

Appendix A

ABEL INVERSION SOFTWARE

This appendix contains documentation and listings for all software related to the Abel Inversion which the author has written in conjunction with the work described in the body of this thesis. Both the program and documentation in Section I is closely related to a program of similar description which may be found in S. A. Goldstein's thesis, Appendix B4, University of Wisconsin, 1973. Also, the appendix in this thesis describing the PEPSUB plotting routine may be helpful. Note that the version of PEPSUB in ABEL3 is an earlier version than described in the PEPSUB appendix, so that line numbering and certain options are slightly different.

I. Program AMXINV2

A. Purpose

AMXINV2 is a FORTRAN program to compute, print, and punch the Area Coefficients and Inverse Area Coefficients needed in order to model a three-dimensional plasma discharge using the Abel Inversion. The program is intended for only irregular use; once

a punched copy of the area coefficients is available, that punched copy can serve indefinitely as a source of the matrices. To determine if there is a need to run the program, check in the group's computer program card file; if you find a block of 1000 cards with something to the effect of "Abel Area Matrices" or "BASIC compatible 50 zone Abel matrices" written on the top of the card deck, there is no need to run AMXINV2; its job is already done.

B. Origins

AMXINV2 is a revised version of program AMXINV, written by R. D. Sacks and modified by S. A. Goldstein. AMXINV did all computations in single precision and punched the area matrices in the form $\pm d.dddd$ where d is a digit from 0 to 9 (thus $1.453 \cdot 10^{-3}$ was punched as 0.0015). In development of some of the current programs, it was found that the limited number of significant figures could pose problems with round-off error. Thus, two modifications have been made in the original program:

- (1) The output has been modified so that both the area matrix and its inverse are listed in full each time the program is run and output is at a constant precision of eight significant figures.
- (2) While only eight figures are output, all computations including the matrix inversion to produce the Inverse Area Coefficients are performed in double precision. At the time the program was modified, checks were run on an HP-45 pocket calculator and on

an IBM 7094 computer to determine the number of significant figures in these double precision calculations--at least ten digits are significant in every entry in the area matrix and its inverse, even though only eight are output as the program is currently set up.

C. Instructions for use

In the group's computer program card file there is a full program deck of AMXINV2 with all control cards and data cards included. To run the program, however, the first card in the program deck (the @RUN card) must be punched so that the third piece of information on the card, the user ID number, corresponds to the actual ID number of the user involved rather than to the user number of the program's author. The @RUN card currently reads:

```
@RUN AS,2231,1893602639,$10.00,100/1100
```

with the @ in column 1. The various numbers have the following meanings:

AS	User's initials
2231	Walter's group project number
1893602639	User's ID number
\$10.00	If running the program exceeds this cost, the run is terminated.

- 100 Maximum number of printout pages permitted
 or else run is terminated.
- 1100 Maximum number of cards which may be punched
 or else job terminates.

It should be evident that the user will want to repunch the card with his own initials and ID number. There MUST be a space after the N in RUN, and there must be no other spaces on the card.

Do not forget any commas or put any extra ones in.

Having punched the @RUN card, replace the original @RUN card with the freshly punched one. The deck may then be run by turning it in for processing in the basement of MACC (the computing center) at 1210 Dayton Street. The job will not run in the WHILE-YOU-WAIT rate group, but can run in any other group (STANDARD, DEFERRED [also known as OVERNIGHT], or CONVENIENCE [also known as WEEKEND]). DEFERRED running is particularly convenient as one can have the program run at a reduced cost rate and still pick it up on the morning after submittal.

When picking up the output, the following items should be given to you: (1) the program deck; (2) a printout showing program compilation and the listing of the area matrices, and (3) a box of computer cards, roughly one-half full, containing the punched area matrices. At both the beginning and end of the punched deck will be some extraneous cards with multiple punches in many of the columns--these should be set aside (if in doubt,

any MACC employee will be able to identify the extraneous cards). The punched deck, less the extraneous cards, should now be interpreted (that is, the cards should be rendered comprehensible by typing the meanings of the hole patterns onto the cards) using either the IBM card interpreter in the basement of MACC or the interpreting keypunch on the ninth floor of the Chemistry Building. Every effort should be made not to "shuffle the deck" as sequence numbers have not been punched onto the cards. If the deck is dropped, however, the printed listing of the matrices may be used to correctly order the cards as discussed in Section F below.

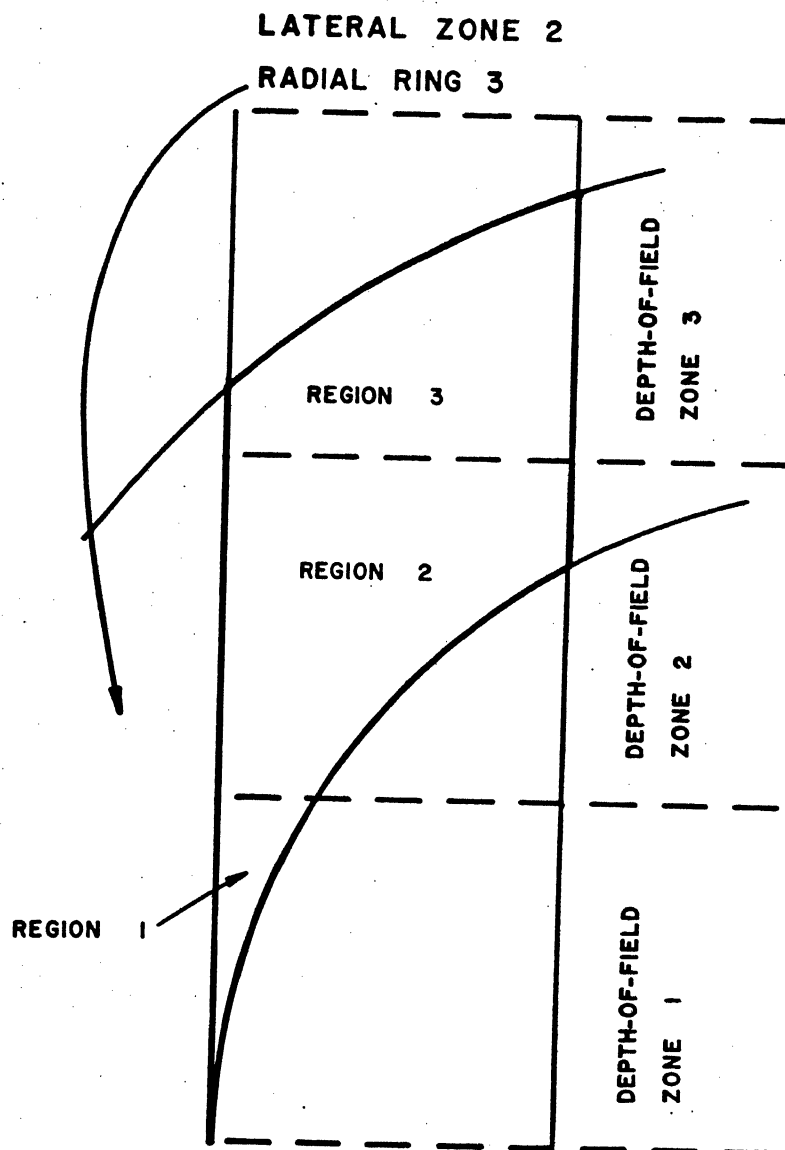
At this point, the purpose for running AMXINV2 has been fulfilled; a punching of the area matrices in a form compatible with the other programs documented herein has been produced. For details on how the matrices were produced and more information about the program, continue with this section. For information on how to load the matrices onto a file to be used with the other programs in this modeling package, go to Section II.

D. How the program works

The method used to compute the segment areas for the Abel Area Matrices is the same as that used by R. D. Sacks and S. A. Goldstein in earlier versions of the program. This involves analytically taking definite integrals of the segment areas, using weighting factors if desired to account for optical

Figure A-1

Definition of Terms for Matrix Computation



locations is then made to compute the region areas (lines 93, 102, 111, 120, 129, 142, 151, 160, and 169 for each of the possible cases). Next, integration is performed over the limits of the region using the proper formulas (Sacks' thesis, p. 267), and the region area is multiplied by a depth-of-field correction factor. (Determination, meaning, and setting of the weighting factors is discussed in Section E.) The segment area is finally computed by summing the area/weighting factor products which make up the segment.

After every segment area has been computed, the entire area matrix is inverted in a call to a matrix inversion subroutine (line 195). The matrix inversion routines are modified versions of the double precision matrix inversion routines from the Madison Academic Computing Center's Basis Unified Matrix Package, revision 2 (BUMP2). Features of this package not pertinent to the inversion of the 50-by-50 area matrix were deleted, and thus the subroutines as given here should be used only as part of this program. The routines are included with the program (instead of using the MACC version which is always on file) so that future changes in BUMP2 need not affect the operation of the program. During compilation the diagnostic "The test for equality between non-integers may not be meaningful." appears six times in Subroutine MSSLVD. These "errors" have intentionally been inserted by the authors of BUMP2 and may thus be ignored.

As the program stands, all output digits are significant. A slight "trick" was necessary in order to have this be the case: As initially calculated, the matrix value in row 2, column 1 of the inverse area matrix was evaluated (due to round-off error) to be $1 \cdot 2^{-60}$ (printed out as $8.6736174 \cdot 10^{-19}$) instead of 0.0 as it should have been. Since a double precision word keeps 60 bits in the mantissa of a number, $1 \cdot 2^{-60}$ is as close to zero as one can get without actually being there. To force the value of the inverse matrix row 2, column 1 to be exactly zero, the statement in line 196 was inserted. All other values are correct without additional manipulation.

Output is performed by a subroutine called PCHSUB. The matrices are printed to eight significant figures, and the lines of output are numbered one to 500 (with five entries per line, that gives all 2500 matrix entries). Each matrix is written onto a scratch file in double precision format, and then read back in and punched in a single precision format compatible with BASIC in general and the other Abel Inversion programs in particular.

E. Program input and deck structure

There are two aspects to loading AMXINV2 into the computer and getting it to run: First, the correct ordering of control cards and the program, and second, entering the desired input data. The punched program deck which is in the group's computer

file is already correctly sequenced for program operation and contains one possible set of input data values. First the deck structure will be discussed, then the input data.

The three stages of execution of the program are: (1) sign-on to the computer, (2) loading the program, and (3) compilation and execution of the program. Sign-on is accomplished with the @RUN card explained in Section C above; the dollar, page, and punch limits entered on the example @RUN card should be sufficient for correct program execution, yet should prevent costly overruns should something go wrong. Loading of the program is accomplished using the FORTRAN compiler; for each subroutine and for the main program, a card is made up which reads:

@FOR,ISZ routine name

where the @ sign is in column 1, there is a space after the Z, and in place of "routine name" is entered the name of the subroutine or program to be loaded. Immediately following the @FOR card, the program or subroutine deck is inserted. After the last subroutine has been loaded, the computer is instructed to load and start the program by using the two card sequence

@MAP,X
@XQT

After the @XQT card, all input data cards for the program are inserted and, at the conclusion of the data, the run is completed by telling the computer that the job is finished by inserting an

@FIN

card. Thus the input deck structure for the program is:

```
@RUN ID,2231,user number,$10.00,100/1100
@FOR,ISZ AMXINV2      (followed by main program deck)
@FOR,ISZ PCHSUB       (followed by subroutine deck)
@FOR,ISZ MTIVD2       (followed by subroutine deck)
@FOR,ISZ MSEROR       (followed by subroutine deck)
@FOR,ISZ MSSLVD       (followed by subroutine deck)
@FOR,ISZ HSSWCH       (followed by subroutine deck)
@FOR,ISZ MSCONV       (followed by subroutine deck)
@FOR,ISZ MSMOVE       (followed by subroutine deck)
@MAP,X
@XQT                  (followed by input data)
@FIN
```

The sequence of cards within a given program or subroutine is given in the listing in Section I.

The only input data for AMXINV2 are the depth-of-field factors. Whatever values are input on the five data cards are the values used for the depth-of-field weighting factors. Fifty factors must be input, ten to a card. All values MUST contain a decimal point, and the numbers MUST be written so that they fill the proper columns on the input cards (FORTRAN demands this syntax). The correct format for the first data card is:

Columns 1-6 Weight factor for the first depth-of-field zone
(zone closest to the center of the discharge)

7-12 Weight factor for the second depth-of-field zone
(zone second closest to the center of the
discharge).

13-18 Third factor

19-24 Fourth factor

25-30 Fifth factor

31-36 Sixth factor

37-42 Seventh factor

43-48 Eighth factor

49-54 Ninth factor

55-60 Tenth factor

There should be no punctuation between the numbers. For purposes of illustration, suppose that all the weight factors were 1.00 except for factors 3 and 7, each of which was 1.2345. Then the data card would appear as:

1.00001.00001.23451.00001.00001.00001.23451.00001.00001.0000

FORTTRAN has a quirk in that a blank on a punched card is read as a zero, so that a slightly more readable format would be:

1.00 1.00 1.23451.00 1.00 1.00 1.23451.00 1.00 1.00

Notice how the rules on decimal points and column usage have been invoked. These are essential. The other four data cards have identical formats, except that the data on card 2 affect depth-of-field zones 11 through 20 etc. up through card 5 affecting depth-of-field zones 41-50. Recall once again that the five cards are inserted between the @XQT card and the @FIN card.

And now that the capability (indeed the necessity) exists for entering the depth-of-field factors, what values should be assigned to them? One possible answer is to say that there is no depth-of-field effect and to set all the factors equal to 1.00. In the cards provided with the program deck in the card file, this is precisely the approach that was taken. If at some time it is determined that a depth-of-field effect is present i.e. that the amount of light which escapes from the discharge is a function not only of the chemistry of the system but also of the distance a particular region of the discharge is from the system collection optics, then some value for the depth-of-field factors other than 1.00 may be appropriate. The point of all this is that depth-of-field factors other than 1.00 may be entered if desired, but that a set of factors all of which equal 1.00 is prepunched and available for use.

F. Program output: interpretation and confirmation

With the program run as currently written, the printed output produced includes a program listing and a printout of the

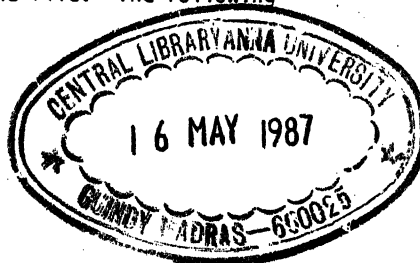
Area and Inverse Abel Area Matrices. A sample printout is included as Section I below, and includes a printout of the two matrices which may be taken as a benchmark when running the program. The order of output is: (1) a label identifying the area matrix; (2) the 2500 elements of the area matrix, printed to eight significant figures, five numbers to a line, with the lines numbered; (3) a label identifying the inverse area matrix; and (4) the inverse matrix in a format identical to that of the area matrix. If the matrices are represented as being subscripted variables X_{ij} and $XINV_{ij}$ where i represents the number of the row of a particular matrix element and j represents the column, then the order of printout is to print $X_{1,1}, X_{1,2}, \dots, X_{1,50}, X_{2,1}$, and so on. That is, all 50 elements of a given row in a matrix are printed out before the next row is started. In the area matrix the i subscript gives the number of the lateral zone to which the particular segment area refers, and the j subscript gives the number of the radial ring containing the segment. As the printout lines are numbered 1 to 500, one can easily tell what row number is referenced in a given printout line; lines 1 through 10 refer to the first row of the matrix, lines 11 to 20 refer to the second row, and so on until lines 491 to 500 refer to the fiftieth row. If the N -th row of a matrix is being examined, then the first $(N-1)$ elements of that row are equal to zero (so that in row 32, there are 31 zeroes followed

author's view that no program is ever "finished", but rather that use of one version of a program will continually inspire ideas for modification; the ideas presented here are the ones that have presented themselves since AMXINV2 was written several months ago. It is hoped that users will invent ideas of their own and decide for themselves whether the modifications might be beneficial.

(1) Rather than punching the matrices onto cards, subroutine PCHSUB could be rewritten to write the matrices onto a file on the 1110's disk memory system directly. This would alleviate one step in bringing the Abel Inversion Plasma Modeling System on-line. Necessary steps would be:

(a) inserting a card assigning a file to contain the output. For example, if a file called ABEL*DATA was to be used for the output, the file would have to be created, saved (so that it is not destroyed at the end of MACC's production day), and assigned a file number so FORTRAN can access the file. The following cards would accomplish this:

```
@ASG,UP ABEL*DATA.
@SAVE,S ABEL*DATA.
@USE 3.,ABEL*DATA.
```



These cards would be inserted between the @RUN card and the first @FOR card, and would allow FORTRAN output file number 3 to be used as the output file for the matrix elements.

(b) modifying PCHSUB so that in place of the statement in line 23

```
PUNCH 70,(B(J),J=1,65)
```

a statement writing the output matrix onto the file was substituted:

```
WRITE(3,70) (B(J),J=1,65)
```

Note that this has never been tried--my suggestion may not work as given!

(2) The program could be rewritten so that matrix dimensions other than 50-by-50 were employed. Considering the output scheme, this could most readily be done if the matrix size was changed in units of five rows/five columns at a time (notice the matrix must always be square). I have not thought out exactly what changes would be needed.

(3) Line 52, which reads in the depth-of-field weighting factors could be rewritten (with a few other additional statements necessary) so that, if no depth-of-field data were supplied, some default value for these factors (probably 1.00) would be automatically computed.

Of these suggestions, only the first promises any significant saving in computing costs. Whether the others are convenient can be decided by the individual user.

H. Meaning of variables

A. Main program--all variables are double precision unless stated otherwise:

X(50,50)	The 50-by-50 matrix of area coefficients.
XINV(50,50)	The 50-by-50 matrix inverse of X(50,50).
DOF(50)	Fifty member array, read in from five data cards, ten values on each card, six characters per datum, containing weighting factors based on depth-of-field effects.
SCRACH(500)	Memory space required for the matrix inversion routine.
I	The lateral zone number (integer).
URY, ULY	Double precision value of I.
LLY, LRY	Double precision value of (I-1).
J	The radial ring number (integer).
XJ	Double precision value of J.
XJTEST	Double precision value of (J-1).
KFIRST	The index for the first depth-of-field zone contained in a given segment X(I,J) (integer).
KLAST	The index for the last depth-of-field zone contained in a given segment X(I,J) (integer).

URX,LRX	Double precision value of KFIRST.
LLX,ULX	Double precision value of (KFIRST-1).
ZX	The largest possible value within a given lateral zone for a segment area X(I,J).
XZX	Truncated value of ZX (integer values stored as real numbers).
LEFT	The radial distance from the origin to the upper left corner of the square formed by the intersection of the I-th lateral zone and the KFIRST-th depth-of-field zone.
HIGH	Radial distance to the upper right corner.
RIGHT	Radial distance to the lower right corner.
LOW	Radial distance to the lower left corner.
YLIMU, YLIMUT, YLIMUB	The upper limit for integration over a region.
YLIML, YLIMLT, YLIMLB	The lower limit of integration over a region.
FACU, FACUT, FACUB	Value of the integral evaluated at the upper limit.
FACL, FACUT, FACLB	Value of the integral evaluated at the lower limit.
AREA, AREAT, AREAB	Area of a region.
CAREA	Area of a region multiplied by the depth-of-field weighting factor.
RV	Real (as opposed to integer) scratch variable.

B. Subroutine PCHSUB--variable types as given:

A(50,50)	Matrix to be output (double precision).
B(65)	Alpha-numeric representation of the numbers to be punched on one card; contains five values from the A matrix at any given time during use.
I	Output line number index (integer).
J	Matrix row index and general utility index (integer).
K, L	General utility indices (integer).
K1, K2	Indices to indicate which columns of row I are to be output (integer).

C. Matrix inversion subroutines. Variables will not be listed as the routines are modifications of MACC's BUMP2 software; meanings of many variables are unclear to the author and the routines have been used as a "black box". Those few changes which were made from the original routines were deletions. Some light may be shed on variable meanings by reading the MACC BUMP2 manual section on "extended calling sequences".

I. Program listing and output

Commencing on the next page is a listing of AMXINV2 and associated subroutines, followed by a complete listing of the Abel Area Matrix and the Inverse Area Matrix for a 50 ring, 50 zone plasma discharge.

SPRT.5 LISTER.AM2INV2
 PURPUR-HACC 4.04 RL1803 06/05-43:27:44

1893402639=LISTER(1).AM2INV2

```

1 C *** PROGRAM AM2INV2....CALCULATION OF AREA MATRIX AND INVERTED
2 C *** AREA MATRIX FOR A 50 ZONE SPARK MODEL.
3 C *** ORIGINALLY WRITTEN BY P. D. SACKS. MODIFIED BY S. A. GLOSTFEN.
4 C *** ADAPTED FOR DOUBLE PRECISION CALCULATION AND BASIC COMPATIBLE
5 C *** OUTPUT BY A. SCHEELINE.
6 C *** PREPARED UNDER THE DIRECTION OF:
7 C *** PROF. JOHN P. WALTERS
8 C *** DEPARTMENT OF CHEMISTRY
9 C *** UNIVERSITY OF WISCONSIN
10 C *** MADISON, WISCONSIN 53706
11 C .....
12 C .....
13 C *** DEFINITION OF VARIABLES.....
14 C *** X(50,50) THE 50-BY-50 MATRIX OF AREA COEFFICIENTS
15 C *** XINV(50,50) THE 50-BY-50 MATRIX OF INVERTED AREA COEFFICIENTS
16 C *** DOF(50) 50 MEMBER ARRAY, READ IN OFF 5 DATA CARDS. 10 VALUES
17 C *** ON EACH CARD, UNDER A 10DE-6 FORMAT, CONTAINING ANY
18 C *** GENERAL CORRECTION FACTOR ALONG THE LINE OF SIGHT
19 C *** SCRWCH(500) MEMORY SPACE REQUIRED FOR THE MATRIX INVERSION ROUTINE
20 C *** I THE OBSERVATION ZONE INDEX
21 C *** URY, ULY THE FLOATING POINT VALUE OF I
22 C *** LLY, LRY THE FLOATING POINT VALUE OF (I - 1)
23 C *** J THE RADIAL ZONE INDEX
24 C *** XJ THE FLOATING POINT VALUE OF J
25 C *** XJTEST THE FLOATING POINT VALUE OF (J - 1)
26 C *** KFIRST THE INDEX FOR THE FIRST LINE-OF-SIGHT ZONE FOR A GIVEN
27 C *** AREA SEGMENT A(I,J)
28 C *** KLAST THE INDEX FOR THE LAST LINE-OF-SIGHT ZONE FOR A GIVEN
29 C *** AREA SEGMENT A(I,J)
30 C *** URX, LRX THE FLOATING POINT VALUE OF KFIRST
31 C *** LLX, ULX THE FLOATING POINT VALUE OF (KFIRST - 1)
32 C *** ZX THE LARGEST VALUE ALONG THE LINE-OF-SIGHT AXIS FOR A
33 C *** GIVEN AREA SEGMENT A(I,J)
34 C *** ZZX THE TRUNCATED VALUE OF ZX
35 C *** LEFT THE RADIAL DISTANCE FROM THE ORIGIN TO THE UPPER LEFT
36 C *** CORNER OF THE SQUARE FORMED BY THE INTERSECTION OF THE
37 C *** I-TH OBSERVATION ZONE AND THE KFIRST LINE-OF-SIGHT ZONE
38 C *** HIGH THE RADIAL DISTANCE TO THE UPPER RIGHT CORNER
39 C *** RIGHT THE RADIAL DISTANCE TO THE LOWER RIGHT CORNER
40 C *** LOW THE RADIAL DISTANCE TO THE LOWER LEFT CORNER
41 C *** ULIMIT THE UPPER LIMIT OF INTEGRATION
42 C *** LLIMIT THE LOWER LIMIT OF INTEGRATION
43 C *** FACU THE VALUE OF THE INTEGRAL EVALUATED AT THE UPPER LIMIT
44 C *** FACL THE VALUE OF THE INTEGRAL EVALUATED AT THE LOWER LIMIT
45 C *** AREA THE AREA OF THE A REGION
46 C *** CAREA THE AREA MULTIPLIED BY THE GENERAL LINE-OF-SIGHT
47 C *** CORRECTION FACTOR
48 C *** RV REAL SCRATCH VARIABLE
49 C .....
50 C .....
51 C DIMENSION SCRWCH(500)
52 C DOUBLE PRECISION X(50,50),XINV(50,50),LLY,LRY,LRX,LLX,LEFT,LOW
53 C DOUBLE PRECISION DOF(50),XJ,URY,ULY,ZX,ZZX,URX,ULX,RIGHT

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```

54      DOUBLE PRECISION HIGH, XJTEST, YLIMU, YLIML, FACU, FACL, AREA, CARFA
55      DOUBLE PRECISION YLIMUT, YLIMLT, FACLT, AREAT, FACUT, YLIMUB, YLIMLB
56      DOUBLE PRECISION FACUB, FACLB, AREAB
57      READ 5, (DOF(K), K = 1, 50)
58      5      FORMAT(10D6.4)
59      PRINT 6, (DOF(K), K = 1, 50)
60      6      FORMAT(1H1, 2L1, 9HDOF ARRAY, // (10F8.3))
61      DO1 I=1, 50
62      DO1 J=1, 50
63      X(I, J)=0.0
64      1      CONTINUE
65      DO10 I=1, 50
66      DO10 J=1, 50
67      IF (I .GT. J) GO TO 99
68      XJ=DFLOAT(J)
69      URY=DFLOAT(I)
70      ULV=URY
71      LLV = URY - 1.0
72      LRV = URY - 1.0
73      IF (I .NE. J) GO TO 16
74      KFIRST = 1
75      16      GOTO 17
76      RV=(1.0+DSQRT((XJ-1.0)**2-URY**2))
77      KFIRST=INT(RV)
78      17      ZX = DSQRT(XJ**2-LLV**2)
79      RXZ = I0INT(ZX)
80      IF (ZX - RXZ) 19, 18, 19
81      19      RXZ = RXZ + 1.0
82      RV=RXZ
83      KLAST=IFIX(RV)
84      70      URX = DFLOAT(KFIRST)
85      LRX=URX
86      LLX=URX-1.0
87      ULX=LLX
88      LEFT =DSQRT(ULX**2 + ULV**2)
89      RIGHT =DSQRT(LRX**2 + LRV**2)
90      LOW =DSQRT(LLX**2 + LLV**2)
91      HIGH =DSQRT(URX**2 + URY**2)
92      XJTEST=XJ-1.0
93      IF (XJTEST .LE. LOW) GO TO 20
94      IF (XJ - HIGH) 40, 50, 50
95      20      IF ((XJ .LE. RIGHT) .AND. (XJ .LE. LEFT)) GO TO 21
96      IF ((XJ .GT. RIGHT) .AND. (XJ .GT. LEFT)) GO TO 23
97      IF (XJ - LEFT) 26, 26, 25
98      21      YLIMU =DSQRT(XJ**2 - LLX**2)
99      YLIML=LLY
100     FACU=0.5*(YLIMU*(DSQRT(XJ**2-YLIMU**2))+XJ**2*(DASIN(YLIMU/XJ)))
101     1-YLIMU*ULX
102     FACL=0.5*(YLIML*(DSQRT(XJ**2-YLIML**2))+XJ**2*(DASIN(YLIML/XJ)))
103     1-YLIML*ULX
104     AREA=FACU-FACL
105     CARFA=AREA*DOF(KFIRST)
106     GOTO 90
107     23      YLIMU=ULV
108     YLIML =DSQRT(XJ**2 - LRV**2)
109     FACU=YLIMU*LRX-0.5*(YLIMU*(DSQRT(XJ**2-YLIMU**2))+XJ**2*(DASIN(
110     1-YLIMU/XJ)))

```

```

111      FACU=VLIML*LN-X-C.5*(VLIML*(DSORT(XJ**2-VLIML**2))*XJ**2*(DASIN(
112      1(VLIML/XJ)))
113      AREA=1.0-(FACU-FACL)
114      CAREA=AREA*DLF(KFIRST)
115      GOTO 90
116  25  VLIMU=ULY
117      VLIML=LLY
118      FACU=0.5*(VLIMU*(DSORT(XJ**2-VLIMU**2))*XJ**2*(DASIN(VLIMU/XJ)))
119      1(VLIMU*(DSORT(XJ**2-ULY**2)))
120      FACL=0.5*(VLIML*(DSORT(XJ**2-VLIML**2))*XJ**2*(DASIN(VLIML/XJ)))
121      1(VLIML*(DSORT(XJ**2-ULY**2)))
122      AREA = FACU - FACL - DSORT(XJ**2-ULY**2) - ULX
123      CAREA=AREA*DLF(KFIRST)
124      GOTO 90
125  26  VLIML =DSORT(XJ**2 - URY**2)
126      VLIMU =DSORT(XJ**2 - LLX**2)
127      FACU=0.5*(VLIMU*(DSORT(XJ**2-VLIMU**2))*XJ**2*(DASIN(VLIMU/XJ)))
128      1(VLIMU*LLX
129      FACL=0.5*(VLIML*(DSORT(XJ**2-VLIML**2))*XJ**2*(DASIN(VLIML/XJ)))
130      1(VLIML*LLX
131      AREA = FACU - FACL - DSORT(XJ**2-URY**2) - LRY
132      CAREA=AREA*DLF(KFIRST)
133      GOTO 90
134  50  XJ=XJ-T.0
135      IF (XJ .GE. PIGHT) .AND. (XJ .GE. LEFT) GO TO 51
136      IF (XJ .LT. RIGHT) .AND. (XJ .LT. LEFT) GO TO 51
137      IF (XJ - LEFT) 55, 56, 56
138  51  VLIMU=URY
139      VLIML =DSORT(XJ**2 - URY**2)
140      FACU=VLIMU*LN-X-C.5*(VLIMU*(DSORT(XJ**2-VLIMU**2))*XJ**2*(DASIN
141      1(VLIMU/XJ)))
142      FACL=VLIML*LN-X-C.5*(VLIML*(DSORT(XJ**2-VLIML**2))*XJ**2*(DASIN
143      1(VLIML/XJ)))
144      AREA=FACU-FACL
145      CAREA=AREA*DLF(KFIRST)
146      GOTO 80
147  53  VLIMU =DSORT(XJ**2 - LLX**2)
148      VLIML=LLY
149      FACU=0.5*(VLIMU*(DSORT(XJ**2-VLIMU**2))*XJ**2*(DASIN(VLIMU/XJ)))
150      1(VLIMU*LLX
151      FACL=0.5*(VLIML*(DSORT(XJ**2-VLIML**2))*XJ**2*(DASIN(VLIML/XJ)))
152      1(VLIML*LLX
153      AREA = 1.0 - (FACU - FACL)
154      CAREA=AREA*DLF(KFIRST)
155      GOTO 80
156  56  VLIMU=URY
157      VLIML=LLY
158      FACU=VLIMU*(DSORT(XJ**2-LLY**2))-0.5*(VLIMU*(DSORT(XJ**2-VLIMU**2
159      1))*XJ**2*(DASIN(VLIMU/XJ)))
160      FACL=VLIML*(DSORT(XJ**2-LLY**2))-0.5*(VLIML*(DSORT(XJ**2-VLIML**2
161      1))*XJ**2*(DASIN(VLIML/XJ)))
162      AREA = FACU - FACL + URY -DSORT(XJ**2-LLY**2)
163      CAREA=AREA*DLF(KFIRST)
164      GOTO 80
165  55  VLIMU =DSORT(XJ**2 - LLX**2)
166      VLIML =DSORT(XJ**2 - URY**2)
167      FACU=VLIMU*LN-X-C.5*(VLIMU*(DSORT(XJ**2-VLIMU**2))*XJ**2*(DASIN(VLIM

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```

168      1U/XJ))
169      FACL=VLIML*U+X-0.5*(VLIML*(DSQRT(XJ**2-VLIML**2))+XJ**2)*BASIN(VLIML
170      1L/XJ))
171      AREA = FACU - FACL * URY -DSQRT(XJ**2-LLX**2)
172      CAREA=AREA*DUF(KFIRST)
173      GOTO80
174      40  VLIMUT=URY
175          VLIMLT =DSQRT(XJ**2 - URY**2)
176          FACUT=VLIMUT*LRX-0.5*(VLIMUT*(DSQRT(XJ**2-VLIMUT**2))+XJ**2)*BASIN
177          1(VLIMUT/XJ))
178          FACLT=VLIMLT*LRX-0.5*(VLIMLT*(DSQRT(XJ**2-VLIMLT**2))+XJ**2)*BASIN
179          1(VLIMLT/XJ))
180          AREAT=FACUT-FACLT
181          XJ=XJ-1.0
182          VLIMUB =DSQRT(XJ**2 - LLX**2)
183          VLIMLB=LLY
184          FACUB=0.5*(VLIMUB*(DSQRT(XJ**2-VLIMUB**2))+XJ**2)*BASIN(VLIMUB/XJ
185          1)) - VLIMUB*LLX
186          FACLB=0.5*(VLIMLB*(DSQRT(XJ**2-VLIMLB**2))+XJ**2)*BASIN(VLIMLB/XJ
187          1)) - VLIMLB*LLX
188          AREAB=FACUB-FACLB
189          AREA=1.0*(AREAT+AREAB)
190          CAREA=AREA*DUF(KFIRST)
191          XJ=XJ-1.0
192          80  K(I,J)=X(I,J)*CAREA
193          90  IF (KFIRST.EQ. KLAST) GO TO 99
194          KFIRST = KFIRST + 1
195          GOTO70
196          99  CONTINUE
197          PRINT 100
198          100  FORMAT(1H ,11NAREA MATRIX)
199          CALL PCMSUB(A)
200          CALL RTIVOZ(A,XINV,50,50,50,'GEN',SCRACH)
201          XINV(2,1)=C.00
202          PRINT 105
203          105  FORMAT(1H ,11VINVERSE AREA MATRIX)
204          CALL PCMSUB(XINV)
205          STOP
206          END
206,N X,P,66,6,3,

```

APRT,5 LISTER,PCNSUB
 PURPUR-MACC 4.04 RL1003 06/05-23:27:45

1893602639=LISTER(1),PCNSUB

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1  SUBROUTINE PCNSUB
2  C --- THIS SUBROUTINE EDITS PRINTS AND PUNCHES 50 BY 50 MATRICES.
3  C --- INPUT IS ASSUMED TO BE A 50 BY 50 DOUBLE PRECISION MATRIX.
4  C --- OUTPUT IS TO 4 SIGNIFICANT FIGURES.
5  DOUBLE PRECISION A(50,50)
6  DIMENSION B(65)
7  I=0
8  DO 30 J=1,50
9  DO 30 K=1,10
10  I=I+1
11  K1=50-K
12  K2=50-K-4
13  PRINT 40,1,(A(J,L),L=K2,K1)
14  40  FORMAT(1H,13,5(1P215.7))
15  WRITE(2,45) (A(J,L),L=K2,K1)
16  45  FORMAT(5(1P214.7))
17  50  CONTINUE
18  REWIND 2
19  DO 80 I=1,500
20  READ(2,60,ERR=100) (B(J),J=1,65)
21  60  FORMAT(15(11A1,1X,2A1))
22  PUNCH 70,(B(J),J=1,65)
23  70  FORMAT(4(1CA1,"E",3A1," ",3,10A1,"E",3A1))
24  80  CONTINUE
25  REWIND 2
26  RETURN
27  100 PRINT 110
28  110 FORMAT(1H,"ERROR IN PUNCHING ROUTINE DURING READING",J,1H,"PROGRAM")
29  CN WILL NOW CASH.
30  STOP
31  END

```

3066,0 2.0,60,0.3.

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0PRT,S LISTER,MTIVD2
FURPUR-MACC 4.04 91803 06/J5-23:27:47

1893602639=LISTER(1),MTIVD2
1  SUBROUTINE MTIVD2 (A,C,NRA,NAROA,NAPCC,TYPEA,SCRACH)
2  C *** ALL MATRIX MANIPULATIONS ARE PERFORMED WITH SUBROUTINES
3  C *** ABSTRACTED FROM MACC'S BUMP2 MATRIX PACKAGE. 6/15/75
4  INTEGER TYPEA
5  DIMENSION SCRACH(1)
6  NAME = 'MTIVD2'
7  INDET = 0
8  INDET = 0
9  ITRUBL = 0
10 IF (NRA .GE. 1 .AND. NAROA .GE. 1 .AND. NAPCC .GE. 1) GO TO 25
11 CALL HSEROR (11,0,NAME,0)
12 STOP
13 IF (TYPEA .EQ. 'GEN' .OR. TYPEA .EQ. 'DIA') GO TO 35
14 CALL HSERUR (0,NAME,C)
15 STOP
16 35 CALL HSSLVDA (0,0,NRA,0,NAROA,0,0,TYPEA,EPS,'INV',C,SCRACH(5+NRA
17 1 + 1),SCRACH(1),SCRACH(NRA+1),SCRACH(2+NRA+1),SCRACH(3+NRA+1),C,
18 2 NAPCC,PV1,'0',C,DET,GETLOG,INDET,ITRUBL)
19 40 IF (INDET .EQ. 1) PV1 = PV1
20 IF (ITRUBL .NE. 0) GO TO 509
21 RETURN
22 999 CALL HSEROR (0,NAME,0)
23 END
2406,4 X-P,66,6,3.

```

3PRT,5 LISTER,MSEROR
 PMPUR-MACC 4.04 RLIM03 06/05-23:27:48

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1893602639=LISTER(11),MSEROR
1  SUBROUTINE MSEROR(ERMESS,NMWORD,SLBRUT,IRET)
2  DIMENSION ERMESS(1)
3  INTEGER ERMESS
4  IF ERMESS(1) .EQ. 0)GO TO 11
5  IF ERMESS(1) .GT. 20 .OR. ERMESS(1) .LT. 0)GO TO 5
6  IERMES = ERMESS(1)
7  PRINT 200
8  200 FORMAT (5A,/)
9  GO TO (3,4,5,6,7,8,103,104,105,106,107),IERMES
10 3 PRINT 91
11 GO TO 11
12 4 PRINT 92
13 GO TO 11
14 5 PRINT 93
15 GO TO 11
16 6 PRINT 94
17 GO TO 11
18 7 PRINT 95
19 GO TO 11
20 8 PRINT 96
21 GO TO 11
22 103 PRINT 97
23 GO TO 11
24 104 PRINT 98
25 GO TO 11
26 105 PRINT 99
27 GO TO 11
28 106 PRINT 80
29 GO TO 11
30 107 PRINT 81
31 GO TO 11
32 9 PRINT 10, (ERMESS(I), I = 1,NMWORD)
33 FORMAT(/,/,10X,5A6)
34 PRINT 12,SUBROUT
35 FORMAT (10X,"MSEROR CALLED FROM",5X,I6)
36 IF (IRET .NE. 0) RETURN
37 PRINT 50
38 50 FORMAT (5X,"JOB ABANDONED")
39 RETURN 0
40 91 FORMAT (5X,"INCOMPATIBLE OPERAND MATRICES")
41 92 FORMAT (5X,"RESULT MATRIX OVERFLOWS OUTPUT ARRAY")
42 93 FORMAT (5X,"LINE OF THE MATRICES CONTAINS RELEASED SPACE")
43 94 FORMAT (5X,"HETEROGENEOUS MATRIX FORMAT")
44 95 FORMAT (5X,"MATRIX IS NOT SQUARE")
45 96 FORMAT (5X,"RESULT MATRIX DIMENSIONS EXCEED OUTPUT ARRAY DIMENSION
46 15")
47 97 FORMAT (5X,"CONVERGENCE FAILURE")
48 98 FORMAT (5X,"INPUT MATRIX OVERLAPS RESULT MATRIX")
49 99 FORMAT (5X,"DOUBLE PRECISION OPERAND MATRIX CONVERTED TO SINGLE PR
50 ECISION")
51 80 FORMAT (5X,"OVERFLOW")
52 81 FORMAT (5X,"MATRIX OR ARRAY DIMENSION LESS THAN ONE")
53 END

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SPRT,5 LISTER,MSLV0
 PURPUR-MACC 4.04 RLINGS 06/05-03:27:49

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1893602639=LISTER(1),MSLV0
1  SUBROUTINE MSLVD(A,B,C,NRA,NCB,MAXRCA,MAXROB,MAXPOC,TYPEA,EPS,
2  OPTYPE,WS1,WS2,INVS1,ICOLSW,IROWSW,RCSCAL,UNSCAL,WS2DIN,PVT,SDIA,
3  Z,SDIB,DET,DETL0G,INDET,ITRUP1)
4  INTEGER TYPEA,OPTYPE,WS2DIN
5  DOUBLE PRECISION A,B,C,WS1,WS2,RCSCAL,TEMP,RATIO,TEMP2,
6  DETEMP,BLGTRP,DET,DETL0G
7  DIMENSION A(MAXROB,NRA),B(MAXROB,NCB),C(MAXPOC,NCB),WS1(WS2DIN),
8  T,NRA),WS2(NRA),INVS1(NRA),ICOLSW(NRA),IROWSW(NRA),RCSCAL(NRA)
9  IF ACCUMULATOR OVERFLOW= 1,1
10  1 NDET = INDET
11  DETEMP = 1.0D
12  BLGTRP = 0.0D
13  ITRUPL = 0
14  IF (TYPEA.NE. 'DIA'.AND. NRA.NE. 1160 TO 65C
15  IF (OPTYPE.NE. 'SLV')GO TO 61C
16  DO 605 I = 1,NRA
17  IF (A(I,1).EQ. C.0)GO TO 997
18  DO 604 J = 1,NCB
19  C(I,J) = B(I,J)/A(I,1)
20  604 CONTINUE
21  605 CONTINUE
22  GO TO 630
23  610 IF (OPTYPE.EQ. 'DET')GO TO 64C
24  IF (OPTYPE.NE. 'INV')GO TO 999
25  DO 620 I = 1,NRA
26  IF (A(I,1).EQ. C.0)GO TO 997
27  WS1(I,1) = (1.0)/A(I,1)
28  620 CONTINUE
29  630 IF (INDET.NE. 1)RETURN
30  640 DET = 1.0
31  DETLOG = 0.0
32  DO 645 I = 1,NRA
33  DETEMP = A(I,1)
34  IF (DETEMP.EQ. C.0)GO TO 995
35  DET = DET * DETEMP
36  DETLOG = DETLOG + DLOG(DABS(DETEMP))
37  645 CONTINUE
38  IF ACCUMULATOR OVERFLOW 994,646
39  646 RETURN
40  650 CALL MSCONV(A,J,A,WS1,NRA,MAXROA,WS2DIN,TYPEA,'GEN',SDIA,'D')
41  IF (OPTYPE.NE. 'SLV')GO TO 2
42  IOP = 1
43  CALL MSROVE (D,O,R,C,NRA,NCB,MAXROB,MAXROC,'GEN',SDIB,'D')
44  GO TO 300
45  2 IF (OPTYPE.EQ. 'INV')GO TO 3
46  IF (OPTYPE.NE. 'DET')GO TO 999
47  NDET = 1
48  IOP = 3
49  GO TO 300
50  3 IOP = 2
51  DO 4 I = 1,NRA
52  RCSCAL(I) = 1.0
53  4 CONTINUE

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54 300 DO 500 I = 1,NRA
55 TEMP = 0.0
56 DO 400 J = 1,NRA
57 IF (DABS(WST(I,J)).LE. TEMP) GO TO 400
58 TEMP2 = WST(I,J)
59 TEMP = DABS(TEMP2)
60 400 CONTINUE
61 IF (TEMP .LE. 0.0) GO TO 595
62 IF (TEMP2 .EQ. 1.0) GO TO 500
63 DO 450 J = 1,NRA
64 WST(I,J) = WST(I,J)/TEMP2
65 450 CONTINUE
66 IF (OPTYPE .EQ. 3MINV) ROSCAL(I) = (1.0)/TEMP2
67 IF (NDIET .EQ. 0) GO TO 451
68 DETEMP = DETEMP * TEMP2
69 DLGTEMP = DLGTEMP + DLOG(DABS(TEMP2))
70 451 IF (OPTYPE .NE. 3MSLV) GO TO 500
71 DO 470 J = 1,NCB
72 C(I,J) = C(I,J)/TEMP2
73 470 CONTINUE
74 500 CONTINUE
75 IF (OPTYPE .EQ. 3MDET) GO TO 7
76 DO 6 I = 1,NRA
77 ICOLSW(I) = I
78 IF (OPTYPE .EQ. 3MINV) IROWSW(I) = I
79 6 CONTINUE
80
81 C
82 BEGIN GAUSS ELIMINATION WITH TOTAL PIVOTTING
83 7 NUPROW = NRA - 1
84 DO 100 JDIAG = 1,NUPROW
85 JGCP = JDIAG + 1
86 JGCR = JDIAG - 1
87 C
88 NOW FIND THE LARGEST ELEMENT OF REMAINING ONES.
89 TEMP = 0.0
90 DO 10 I = JDIAG,NRA
91 DO 20 J = JDIAG,NRA
92 IF (DABS(WST(I,J)).LE. TEMP) GO TO 20
93 8 PAXR = I
94 PAXC = J
95 TEMP = DABS(WST(I,J))
96 20 CONTINUE
97 10 CONTINUE
98 IF (JDIAG .NE. 1) GO TO 12
99 PVT = TEMP
100 12 IF (TEMP .GE. PVT) GO TO 14
101 PVT = TEMP
102 14 IF (TEMP .EQ. 0.0) GO TO 505
103 IF (PAXR .EQ. JDIAG) GO TO 50
104 SWAP ROWS JDIAG AND PAXR.
105 C
106 40 ISTEOL = JDIAG
107 IF (OPTYPE .NE. 3MINV) GO TO 45
108 ISTEOL = 1
109 45 DO 46 J = ISTEOL,NRA
110 TEMP = WST(PAXR,J)
111 WST(PAXR,J) = WST(JDIAG,J)
112 WST(JDIAG,J) = TEMP
113 46 CONTINUE

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111      DETEMP = - DTEMP
112      IF (COPTYPE .EQ. 3) DET = GO TO 50
113      IF (COPTYPE .NE. 3) SLV = GO TO 49
114      DO 48 J = 1, NCB
115          TEMP = C(MAXC, J)
116          C(MAXC, J) = C(JDIAG, J)
117          C(JDIAG, J) = TEMP
118      48 CONTINUE
119      GO TO 50
120  C      BOOKKEEP ROW SWAP FOR INVERSE
121      49 ITEMP = IROWSW(JDIAG)
122      IROWSW(JDIAG) = IROWSW(MAXC)
123      IROWSW(MAXC) = ITEMP
124      50 IF (MAXC .EQ. JDIAG) GO TO 70
125  C      SWAP COLUMNS JDIAG AND MAXC
126      DO 65 I = 1, NRA
127          TEMP = WST(I, MAXC)
128          WST(I, MAXC) = WST(I, JDIAG)
129          WST(I, JDIAG) = TEMP
130      65 CONTINUE
131      IF (COPTYPE .EQ. 3) DET = GO TO 66
132  C
133  C      NOW DO BOOKKEEPING FOR COLUMN SWAP
134      TEMP = ICOLSW(JDIAG)
135      ICOLSW(JDIAG) = ICOLSW(MAXC)
136      ICOLSW(MAXC) = TEMP
137      66 DETEMP = -DETTEMP
138  C      NOW ELIMINATE COLUMN JDIAG
139      70 DO 80 I = JDU, NRA
140          RATIO = WST(I, JDIAG) / WST(JDIAG, JDIAG)
141          ISTEOL = JOGP
142          DO 70 (66, 67, 68), IOP
143  C      60 TO 67 IF INV
144          67 ISTEOL = 1
145          DO 72 J = ISTEOL, NRA
146              WST(I, J) = WST(I, J) - RATIO * WST(JDIAG, J)
147          72 CONTINUE
148          GO TO (76, 75, 80), IOP
149  C      76 IF SLV      75 IF INV      80 IF DET
150          76 DO 74 J = 1, NCB
151              C(I, J) = C(I, J) - RATIO * C(JDIAG, J)
152          74 CONTINUE
153          GO TO 80
154  C      FILL IN LOWER PART OF COLUMN JDIAG WITH INVERSE ELEMENTS
155          75 ITEMP3 = IROWSW(JDIAG)
156          WST(I, JDIAG) = -POSVAL(ITEMP3) * RATIO
157      80 CONTINUE
158      IF ACCUMULATOR OVERFLOW = 594, 100
159      100 CONTINUE
160      IF (WST(NRA, NRA) .EQ. 0.0) GO TO 995
161      IF (NDET .EQ. 0) GO TO 104
162      DET = DETEMP
163      DETLOG = DLGTEMP
164      DO 101 I = 1, NRA
165          DETEMP = WST(I, I)
166          DET = DET * DETEMP
167          DETLOG = DETLOG + DLOG(DABS(DETEMP))

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```

168      101 CONTINUE
169      IF ACCUMULATOR OVERFLOW 994,102
170      102 IF (OPTYPE .EQ. 'DET') RETURN
171      104 IF (PVT .LT. EPS) GO TO 994
172      C
173      C      NOW DO BACK SUBSTITUTION
174      C
175      105 NDCOL = NCB
176      IF (OPTYPE .NE. 3MINV) GO TO 120
177      NDCOL = NRA
178      120 DO 175 JDIAG = NRA,1,-1
179      JGCP = JDIAG + 1
180      GO TO (14J,134),IOP
181      C      134 IF SLV      140 IF INV
182      134 ITEMP3 = IROWSW(JDIAG)
183      DO 135 J = JDIAG,NRA
184      WS2(J) = WST(JDIAG,J)
185      135 CONTINUE
186      C      MUST SAVE ROW JDIAG AS IT GETS Clobbered
187      140 DO 170 M = 1,NDCOL
188      GO TO (16J,141),IOP
189      C      140 IF SLV      141 IF INV
190      141 TEMP = WST(JDIAG,M)
191      IF (M .LT. JDIAG) GO TO 154
192      TEMP = 0.0
193      IF (M .NE. JDIAG) GO TO 154
194      TEMP = ROSCAL(ITEMP3)
195      154 IF (JDIAG .EQ. NRA) GO TO 156
196      DO 155 J = JGCP,NRA
197      TEMP = TEMP - WS2(J)*WST(J,P)
198      155 CONTINUE
199      156 WST(JDIAG,M) = TEMP/WS2(JDIAG)
200      GO TO 170
201      160 TEMP = C(JDIAG,M)
202      IF (JDIAG .EQ. NRA) GO TO 166
203      DO 165 J = JGCP,NRA
204      TEMP = TEMP - WST(JDIAG,J)*C(J,M)
205      165 CONTINUE
206      C(JDIAG,M) = TEMP/WST(JDIAG,JDIAG)
207      170 CONTINUE
208      175 CONTINUE
209      C
210      C      NEXT REORDER ROWS AND RESCALE UNKNOWN (ROWS).
211      C
212      DO 181 I = 1,NRA
213      ITEMP3 = ICOLS(I)
214      WST(ITEMP3) = 1
215      181 CONTINUE
216      DO 190 I = 1,NRA
217      ITEMPOR = IWS1(I)
218      IF (ITEMPOR .EQ. 1) GO TO 190
219      IF (OPTYPE .NE. 3MINV) GO TO 185
220      DO 184 J = 1,NRA
221      TEMP = WST(I,J)
222      WST(I,J) = WST(ITEMPOR,J)
223      WST(ITEMPOR,J) = TEMP
224      184 CONTINUE
225      GO TO 189

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225      185 DO 188 J = 1,NCB
226          TEMP = C(I,J)
227          C(I,J) = C(ITMPOR,J)
228          C(ITMPOR,J) = TEMP
229      188 CONTINUE
230      C      NOW BOOKKEEP ROWSWITCH USING COLSWCH
231      189 CALL MSSWCH(I,COLSW,IWS1,ITMPOR,I,NRA)
232      190 CONTINUE
233          IF (COPTYPE .NE. 3)MINV) GO TO 2C0
234      C      FINALLY REORDER COLUMNS FOR INVERSE
235      DO 192 I = 1,NRA
236          ITMPOR = IROWSW(I)
237          IWS1(ITMPOR) = I
238      192 CONTINUE
239          DO 198 J = 1,NRA
240              ITMPOR = IWS1(J)
241              IF (ITMPOR .EQ. J) GO TO 198
242              DO 194 I = 1,NRA
243                  TEMP = WS1(I,ITMPOR)
244                  WS1(I,ITMPOR) = WS1(I,J)
245                  WS1(I,J) = TEMP
246      194 CONTINUE
247      C      NOW BOOKKEEP INVERSE COLUMN SWITCH
248      CALL MSSWCH (IROWSW,IWS1,ITMPOR,J,NRA)
249      198 CONTINUE
250      200 IF ACCUMULATOR OVERFLOW 594,201
251      201 RETURN
252      995 IF (COPTYPE .NE. 'DET')GO TO 997
253          DET = 0.00
254          DETLOG=-1.06
255          RETURN
256      994 CALL MSError('OVERFLOW',2,'HSSLVD',1)
257          ITRABL = 1
258          RETURN
259      997 CALL MSError('SINGULAR MATRIX',3,'HSSLVD',1)
260          ITRABL = 1
261          RETURN
262      998 PRINT 990
263          PRINT 991,PVT
264          GO TO 105
265      990 FORMAT(1X,'WARNING. THE MATRIX IS NEARLY SINGULAR')
266      991 FORMAT (1X,'PIVOT ELEMENT = ',E10.9)
267      999 CALL MSError(4,0,'HSSLVD',1)
268          RETURN
269      END
270 2706,N 2.P,66,6,3.

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@PRT,S LISTER.MSSUCH
FURPUR-WACC 4.04 RL1803 06/65-23:27:50
1893402639=LISTER(1).MSSUCH
1  SUBROUTINE MSS=CHCIS=.INST,A,B,NRA)
2  INTEGER A,B
3  DIMENSION ISW(NRA),INST(NRA)
4  ITHPOR = ISW(A)
5  INST(ITHPOR) = B
6  ITHPOR = ISW(B)
7  INST(ITHPOR) = A
8  ISW(B) = ISW(A)
9  ISW(A) = ITHPOR
10 END
2H06,N 1.M,00,4,3.

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DPRT,3 LISTER-MSCONV
 FURPUR-MACC 4.04 ALIB03 06/J5-43:27:51

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1893602639=LISTER(1),MSCONV
1  SUBROUTINE MSCONV(CA,C,AA,CC,NRA,MAXPOA,MAXROC,TYPEA,TYPEC,SDIA,
2  1SDIC)
3  DIMENSION A(MAXROA,NRA),AA(MAXROA,NPA),C(MAXROC,NPA),CC(MAXPOC,
4  1NRA)
5  INTEGER TYPEA,TYPEC,SDIA,SDIC
6  DOUBLE PRECISION AA,CC
7  ISNGDB = 1
8  IF (SDIA .EQ. 'D') ISNGDB = ISNGDB + 1
9  IF (SDIC .EQ. 'D') ISNGDB = ISNGDB + 2
10 IF ((TYPEA.EQ.3HGEN).AND.(TYPEC.EQ.3HGEN))GO TO 20
11 GO TO 999
12 20 IF (MAXROC .NE. MAXROA)GO TO 2C9
13 IF (ISNGDB .NE. 1)GO TO 2C1
14 IF (LOC(A(1,1)) .NE. LOC(C(1,1)))GO TO 209
15 GO TO 2C2
16 201 IF (ISNGDB .NE. 4)GO TO 2C0
17 IF (LOC(AA(1,1)) .NE. LOC(CC(1,1)))GO TO 2C0
18 202 DO 208 J = 1,NRA
19 DO 207 I = 1,NPA
20 GO TO (203,203,206,206),ISNGDB
21 203 C(I,J) = A(I,J)
22 GO TO 207
23 204 CC(I,J) = AA(I,J)
24 207 CONTINUE
25 206 CONTINUE
26 RETURN
27 209 DO 21 J = NRA,1,-1
28 DO 21 I = NPA,1,-1
29 GO TO (221,222,223,224),ISNGDB
30 221 C(I,J) = A(I,J)
31 GO TO 21
32 222 C(I,J) = AA(I,J)
33 GO TO 21
34 223 CC(I,J) = A(I,J)
35 GO TO 21
36 224 CC(I,J) = AA(I,J)
37 21 CONTINUE
38 RETURN
39 999 CALL MERROR(4,3,'MSCONV',0)
40 RETURN
41 END

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PREC 17

NRCO 71

2H86,N 1.P,46,0,3.

BPRT-5 LISTER.MSPOVE
FURPUR-MACC 4.04 RL1803 06/US-43:27:52

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1893402639=LISTER(1).MSPOVE
1      SUBROUTINE MSPOVE(A,C,AA,CC,NRA,NCA,MAXROA,"MAXROC",TYPEA,SDIA,SDIC)
2      DIMENSION A(MAXROA,NCA),C(MAXROC,NCA),AA(PAXROA,NCA),CC(MAXPOC,
3      1 NCA)
4      INTEGER TYPEA,SDIA,SDIC
5      DOUBLE PRECISION AA,CC
6      ISNGDB = 1
7      IF (SDIA .EQ. 'B') ISNGDB = ISAGDB + 1
8      IF (SDIC .EQ. 'D') ISNGDB = ISAGDB + 2
9      IF (TYPEA .NE. 'GEN') GO TO 11
10     10 GO TO 110 J = NCA,1,-1
11     11 GO TO 9 I = NRA,1,-1
12     12 GO TO (10G,1L1,10Z,1C3),ISNGDB
13     100 C(I,J) = A(I,J)
14     14 GO TO 109
15     15 C(I,J) = AA(I,J)
16     16 GO TO 109
17     17 C(I,J) = A(I,J)
18     18 GO TO 109
19     19 C(I,J) = AA(I,J)
20     20 CONTINUE
21     21 CONTINUE
22     RETURN
23     23 IF (TYPEA .NE. 'SYM') GO TO 21
24     24 NOEL=(NRA+(NCA+1))/2
25     25 GO TO 30
26     26 IF (TYPEA .NE. 'DIA') GO TO 999
27     27 NOEL = NRA
28     28 GO TO 40 I = NOEL,1,-1
29     29 GO TO (31,32,33,34),ISNGDB
30     30 C(I,1) = A(I,1)
31     31 GO TO 40
32     32 C(I,1) = AA(I,1)
33     33 GO TO 40
34     34 C(I,1) = A(I,1)
35     35 GO TO 40
36     36 C(I,1) = AA(I,1)
37     40 CONTINUE
38     RETURN
39     999 CALL MZEROR(4,0,"MSPOVE",0)
40     RETURN
41     END

```

PRPG P

PRPG 1C

PRPG 11

PRPG 12

PRPG 12

3806,N X,R,66,6,3.

SPRT,S LISTER,RUNSTREAM
 FURPUR-WACC 4,G4 RL1603 06/65-23:27:54

1893602639-LISTER(1),RUNSTREAM

1	BFOR,ISC	APRINV4									
2	BFOR,ISC	PCHSL6									
3	BFOR,ISC	RTIWB2									
4	BFOR,ISC	MSEROR									
5	BFOR,ISC	MSSLV6									
6	BFOR,ISC	MSSLCH									
7	BFOR,ISC	MSCONV									
8	BFOR,ISC	MSNOVE									
9	BMAP,X										
10	BMGT										
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

BMGC,N 2,P,66,6,3.

ANEL AREA MATRICES—AREA MATRIX

PAGE 1 ROWS 1- 5

1	7.8539816-001	1.1278248-000	1.0302547-000	1.0144541-000	1.0085300-000
2	1.0056416-000	1.0040117-000	1.0030005-000	1.0023295-000	1.0018412-000
3	1.0015214-000	1.0012670-000	1.0010715-000	1.0009180-000	1.0000795-000
4	1.0004958-000	1.0006138-000	1.0005455-000	1.0004880-000	1.0000391-000
5	1.0003973-000	1.0003611-000	1.0003297-000	1.0003022-000	1.0002760-000
6	1.0002546-000	1.0002376-000	1.0002206-000	1.0002054-000	1.0001917-000
7	1.0001793-000	1.0001681-000	1.0001579-000	1.0001486-000	1.0001401-000
8	1.0001323-000	1.0001252-000	1.0001186-000	1.0001125-000	1.0001069-000
9	1.0001017-000	1.0000968-000	1.0000923-000	1.0000881-000	1.0000842-000
10	1.0000805-000	1.0000771-000	1.0000739-000	1.0000709-000	1.0000680-000
11	0.0000000-001	1.2283697-000	1.3479931-000	1.1185953-000	1.0651144-000
12	1.0417408-000	1.0291903-000	1.3216137-000	1.0164703-000	1.0132502-000
13	1.0108032-000	1.0088947-000	1.0075759-000	1.0064815-000	1.0056000-000
14	1.0049019-000	1.0043210-000	1.0038377-000	1.0034313-000	1.0030844-000
15	1.0027910-000	1.0025362-000	1.0022314-000	1.0021212-000	1.0019509-000
16	1.0018004-000	1.0016667-000	1.0015473-000	1.0014403-000	1.0013441-000
17	1.0012572-000	1.0011794-000	1.0011066-000	1.0010417-000	1.0009820-000
18	1.0009274-000	1.0008772-000	1.0008310-000	1.0007883-000	1.0007468-000
19	1.0007122-000	1.0006783-000	1.0006467-000	1.0006173-000	1.0005893-000
20	1.0005442-000	1.0005401-000	1.0005176-000	1.0004965-000	1.0004760-000
21	0.0000000-001	0.0000000-001	1.5487410-000	1.5514907-000	1.2169956-000
22	1.1278604-000	1.0859450-000	1.3422267-000	1.0473226-000	1.0372834-000
23	1.0301737-000	1.0244427-000	1.0209762-000	1.0178938-000	1.0154491-000
24	1.0134764-000	1.0114610-000	1.0105211-000	1.0093979-000	1.0084447-000
25	1.0076307-000	1.0069294-000	1.0063208-000	1.0057892-000	1.0053222-000
26	1.0049096-000	1.0045433-000	1.0042166-000	1.0039240-000	1.0036609-000
27	1.0034234-000	1.0032084-000	1.0030130-000	1.0028350-000	1.0026723-000
28	1.0025232-000	1.0023963-000	1.0022603-000	1.0021440-000	1.0020366-000
29	1.0019368-000	1.0018443-000	1.0017583-000	1.0016781-000	1.0016034-000
30	1.0015335-000	1.0014681-000	1.0014068-000	1.0013492-000	1.0012952-000
31	0.0000000-001	0.0000000-001	0.0000000-001	1.8132470-000	1.7341793-000
32	1.3129368-000	1.1926253-000	1.1335893-000	1.0990625-000	1.0767891-000
33	1.0614544-000	1.0503922-000	1.0421237-000	1.0357674-000	1.0307482-000
34	1.0267612-000	1.0234973-000	1.0206018-000	1.0185489-000	1.0164460-000
35	1.0150237-000	1.0136290-000	1.0124210-000	1.0113677-000	1.0104439-000
36	1.0096282-000	1.0089052-000	1.0082610-000	1.0076845-000	1.0071663-000
37	1.0066994-000	1.0062766-000	1.0058927-000	1.0055431-000	1.0052738-000
38	1.0049314-000	1.0046629-000	1.0044158-000	1.0041879-000	1.0039772-000
39	1.0037821-000	1.0036010-000	1.0034326-000	1.0032758-000	1.0031295-000
40	1.0029928-000	1.0028649-000	1.0027450-000	1.0026325-000	1.0025266-000
41	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	2.0437630-000
42	1.9004225-000	1.4043927-000	1.2545577-000	1.1819523-000	1.1373397-000
43	1.1080120-000	1.0874961-000	1.0724910-000	1.0611394-000	1.0523200-000
44	1.0453178-000	1.0394576-000	1.0350119-000	1.0311487-000	1.0278994-000
45	1.0251394-000	1.0227737-000	1.0207302-000	1.0195523-000	1.0173956-000
46	1.0160245-000	1.0148105-000	1.0137303-000	1.0127449-000	1.0118984-000
47	1.0111177-000	1.0104117-000	1.0097713-000	1.0091844-000	1.0086544-000
48	1.0081645-000	1.0077227-000	1.0073117-000	1.0069327-000	1.0065826-000
49	1.0064254-000	1.0060577-000	1.0056782-000	1.0054179-000	1.0051752-000
50	1.0049485-000	1.0047364-000	1.0045377-000	1.0043513-000	1.0041761-000

ABEL AREA MATRICES—AREA MATRIX

PAGE 2 ROWS 6-10

51	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
52	2.2507778-000	2.0537264-000	1.4912840-000	1.3187503-000	1.2299409-000
53	1.1759596-000	1.139739-000	1.1144930-000	1.0954544-000	1.0812704-000
54	1.0649945-000	1.0409404-000	1.0536404-000	1.0475779-000	1.0425075-000
55	1.0382204-000	1.0345611-000	1.0314106-000	1.0286776-000	1.0242911-000
56	1.0241937-000	1.0223403-000	1.0206940-000	1.0192249-000	1.0179081-000
57	1.0167233-000	1.0156531-000	1.0146831-000	1.0138012-000	1.0129970-000
58	1.0122614-000	1.0115869-000	1.0109669-000	1.0103956-000	1.0098660-000
59	1.0093798-000	1.0089270-000	1.0085065-000	1.0081150-000	1.0077501-000
60	1.0074093-000	1.0070907-000	1.0067922-000	1.0065122-000	1.0062492-000
61	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
62	0.0000000-001	2.4402844-000	2.1946049-000	1.5739761-000	1.3789493-000
63	1.2770737-000	1.2143754-000	1.1721238-000	1.1419148-000	1.1193988-000
64	1.1020477-000	1.0883934-000	1.0773246-000	1.0683723-000	1.0608894-000
65	1.0546007-000	1.0492597-000	1.0446615-000	1.0407249-000	1.0372804-000
66	1.0342621-000	1.0316913-000	1.0292431-000	1.0271426-000	1.0252633-000
67	1.0235748-000	1.0220514-000	1.0206732-000	1.0194211-000	1.0182804-000
68	1.0172382-000	1.0162433-000	1.0155062-000	1.0145986-000	1.0138533-000
69	1.0131640-000	1.0125252-000	1.0119321-000	1.0113804-000	1.0108462-000
70	1.0103663-000	1.0099377-000	1.0095174-000	1.0091238-000	1.0087500-000
71	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
72	0.0000000-001	0.0000000-001	2.4160944-000	2.3308946-000	1.4528954-000
73	1.4371453-000	1.3231526-000	1.2523072-000	1.2041513-000	1.1694587-000
74	1.1434121-000	1.1232399-000	1.1072320-000	1.0942763-000	1.0836184-000
75	1.0747294-000	1.0672279-000	1.0608323-000	1.0553303-000	1.0505533-000
76	1.0463929-000	1.0427310-000	1.0394941-000	1.0366177-000	1.0340494-000
77	1.0317461-000	1.0296721-000	1.0277975-000	1.0260973-000	1.0245503-000
78	1.0231343-000	1.0218440-000	1.0206601-000	1.0195691-000	1.0185633-000
79	1.0174333-000	1.0167722-000	1.0159732-000	1.0152303-000	1.0145385-000
80	1.0138931-000	1.0132900-000	1.0127255-000	1.0121965-000	1.0117000-000
81	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
82	0.0000000-001	0.0000000-001	0.0000000-001	2.7809084-000	2.4579515-000
83	1.7249507-000	1.4934227-000	1.3681112-000	1.2696136-000	1.2358788-000
84	1.1949194-000	1.1674999-000	1.1445941-000	1.1263283-000	1.1114784-000
85	1.0992115-000	1.0889409-000	1.0802422-000	1.0728008-000	1.0663791-000
86	1.0640799-000	1.0559033-000	1.0515935-000	1.0477745-000	1.0443729-000
87	1.0413290-000	1.0385935-000	1.0361254-000	1.0338904-000	1.0318597-000
88	1.0300086-000	1.0283167-000	1.0267657-000	1.0253401-000	1.0240268-000
89	1.0228142-000	1.0214920-000	1.0206514-000	1.0198846-000	1.0187843-000
90	1.0179459-000	1.0171423-000	1.0164244-000	1.0157429-000	1.0150987-000
91	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
92	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
93	2.5748161-000	1.8010005-000	1.5478990-000	1.4119472-000	1.3242279-000
94	1.2672093-000	1.2241816-000	1.1915336-000	1.1659995-000	1.1455526-000
95	1.1288451-000	1.1150303-000	1.1034081-000	1.0935335-000	1.0850612-000
96	1.0777294-000	1.0713366-000	1.0657243-000	1.0607674-000	1.0563651-000
97	1.0524359-000	1.0489129-000	1.0464308-000	1.0442837-000	1.0422730-000
98	1.0379061-000	1.0357454-000	1.0337672-000	1.0319512-000	1.0302800-000
99	1.0287184-000	1.0273130-000	1.0259924-000	1.0247465-000	1.0236263-000
100	1.0225639-000	1.0215723-000	1.0206453-000	1.0197773-000	1.0189435-000

ABNL AREA MATRICES—AREA MATRIX

PAGE 3 ROWS 11-15

101	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
102	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
103	3.0819513-000	2.4993072-000	1.8708528-000	1.4004989-000	1.4546901-000
104	1.3621257-000	1.2980720-000	1.2511499-000	1.2154287-000	1.1873465-000
105	1.1448137-000	1.1443554-000	1.1309859-000	1.1180446-000	1.1070187-000
106	1.0975339-000	1.0893354-000	1.0821144-000	1.0757873-000	1.0701873-000
107	1.0652041-000	1.0607799-000	1.0567453-000	1.0531352-000	1.0498669-000
108	1.0464977-000	1.0441914-000	1.0417173-000	1.0394491-000	1.0373642-000
109	1.0354431-000	1.0336688-000	1.0320265-000	1.0305012-000	1.0290875-000
110	1.0277695-000	1.0265401-000	1.0253917-000	1.0243170-000	1.0233099-000
111	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
112	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
113	0.0000000-001	3.2248527-000	2.8050783-000	1.9382753-000	1.4519436-000
114	1.4963844-000	1.3973061-000	1.3284532-000	1.2778393-000	1.2391292-000
115	1.2086329-000	1.1840644-000	1.1638530-000	1.1470120-000	1.1327852-000
116	1.1206342-000	1.1101572-000	1.1010442-000	1.0930704-000	1.0860374-000
117	1.0798006-000	1.074212-000	1.0692612-000	1.0647807-000	1.0607333-000
118	1.0570637-000	1.0537250-000	1.0504779-000	1.0478887-000	1.0453283-000
119	1.0429721-000	1.0407864-000	1.0387885-000	1.0369262-000	1.0351971-000
120	1.0335885-000	1.0322584-000	1.0306900-000	1.0293814-000	1.0281553-000
121	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
122	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
123	0.0000000-001	0.0000000-001	3.3598496-000	2.9116611-000	2.3034924-000
124	1.7017443-000	1.5372808-000	1.4317821-000	1.3583370-000	1.3041432-000
125	1.2425984-000	1.2297554-000	1.2032039-000	1.1813389-000	1.1630586-000
126	1.1475802-000	1.1343308-000	1.1228829-000	1.1129099-000	1.1041589-000
127	1.0944305-000	1.0835654-000	1.0834358-000	1.0779365-000	1.0729815-000
128	1.0664991-000	1.0644274-000	1.0607221-000	1.0573342-000	1.0542292-000
129	1.0513758-000	1.0487449-000	1.0463191-000	1.0440720-000	1.0419876-000
130	1.0400507-000	1.0382471-000	1.0365647-000	1.0349928-000	1.0335217-000
131	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
132	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
133	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0144953-000
134	2.0447215-000	1.7502103-000	1.5768313-000	1.4655740-000	1.3877231-000
135	1.3301273-000	1.2358132-000	1.2507040-000	1.2222527-000	1.1987672-000
136	1.1790888-000	1.1623913-000	1.1480703-000	1.1356729-000	1.1245535-000
137	1.1153435-000	1.1049311-000	1.0994470-000	1.0927544-000	1.0867418-000
138	1.0813164-000	1.0764024-000	1.0719353-000	1.0678609-000	1.0641333-000
139	1.0607132-000	1.0575649-000	1.0546651-000	1.0519826-000	1.0494974-000
140	1.0471971-000	1.0450439-000	1.0430438-000	1.0411766-000	1.0394306-000
141	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
142	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
143	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
144	3.1139487-000	2.1280714-000	1.7974298-000	1.4156874-000	1.4987063-000
145	1.9166179-000	1.3557261-000	1.3087593-000	1.2714631-000	1.2411687-000
146	1.2161111-000	1.1450736-000	1.1771892-000	1.1618225-000	1.1484973-000
147	1.1368491-000	1.1255947-000	1.1175102-000	1.1094167-000	1.1021643-000
148	1.0956446-000	1.0897596-000	1.0844152-000	1.0795569-000	1.0751180-000
149	1.0710527-000	1.0673188-000	1.0638804-000	1.0607062-000	1.0577691-000
150	1.0550457-000	1.0525150-000	1.0501591-000	1.0479618-000	1.0459088-000

ABTL AREA MATRICES--AREA MATRIX

PAGE 4 ROWS 16-20

151	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
152	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
153	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
154	3.7356811-000	3.2103332-000	2.1877515-000	1.8434897-000	1.6536981-000
155	1.5312051-000	1.4450322-000	1.3809594-000	1.3314289-000	1.2920141-000
156	1.2599350-000	1.2333509-000	1.2109916-000	1.1919510-000	1.1755441-000
157	1.1613321-000	1.1486727-000	1.1378885-000	1.1281442-000	1.1194515-000
158	1.1116578-000	1.1046381-000	1.0982692-000	1.0925251-000	1.0872736-000
159	1.0824734-000	1.0740728-000	1.0740271-000	1.0702981-000	1.0666526-000
160	1.0636617-000	1.0607004-000	1.0579466-000	1.0553808-000	1.0529660-000
161	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
162	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
163	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
164	0.0000000-001	3.8528193-000	3.3039156-000	2.2458703-000	1.4888464-000
165	1.6909098-000	1.5630969-000	1.4729790-000	1.4058307-000	1.3538189-000
166	1.3123507-000	1.2785396-000	1.2504720-000	1.2268269-000	1.2064589-000
167	1.1892764-000	1.1741581-000	1.1609047-000	1.1492053-000	1.1388135-000
168	1.1295319-000	1.1212007-000	1.1136884-000	1.1068869-000	1.1007053-000
169	1.0950678-000	1.0896100-000	1.0851771-000	1.0808220-000	1.0768044-000
170	1.0730891-000	1.0696454-000	1.0664473-000	1.0634709-000	1.0606957-000
171	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
172	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
173	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
174	0.0000000-001	0.0000000-001	3.9444995-000	3.3949262-000	2.3025526-000
175	1.9324305-000	1.7273654-000	1.5944082-000	1.5004729-000	1.4303463-000
176	1.3755290-000	1.3324684-000	1.2949745-000	1.2674460-000	1.2425457-000
177	1.2212994-000	1.2029447-000	1.1849600-000	1.1729295-000	1.1605291-000
178	1.1495020-000	1.1396420-000	1.1307820-000	1.1227848-000	1.1155369-000
179	1.1084943-000	1.1029247-000	1.0974131-000	1.0923512-000	1.0874894-000
180	1.0833856-000	1.0794024-000	1.0757078-000	1.0722739-000	1.0690758-000
181	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
182	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
183	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
184	0.0000000-001	0.0000000-001	0.0000000-001	4.0770110-000	3.4835455-000
185	2.3579696-000	1.9754436-000	1.7631061-000	1.6251644-000	1.5275290-000
186	1.9545136-000	1.3977615-000	1.3523651-000	1.3152346-000	1.2843193-000
187	1.2582001-000	1.2358617-000	1.2145575-000	1.1997255-000	1.1849343-000
188	1.1714449-000	1.1601964-000	1.1497683-000	1.1403884-000	1.1319139-000
189	1.1242262-000	1.1172264-000	1.1108313-000	1.1049702-000	1.0995829-000
190	1.0946177-000	1.0900299-000	1.0857810-000	1.0818372-000	1.0781690-000
191	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
192	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
193	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
194	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	4.1846049-000
195	3.5700093-000	2.4119416-000	2.3175630-000	1.7981485-000	1.6553901-000
196	1.9541629-000	1.4783419-000	1.4193203-000	1.3720407-000	1.3333171-000
197	1.3010329-000	1.2737228-000	1.2503377-000	1.2301055-000	1.2124448-000
198	1.1969086-000	1.1831474-000	1.1708657-000	1.1598996-000	1.1500087-000
199	1.1410644-000	1.1329435-000	1.1255432-000	1.1187767-000	1.1125703-000
200	1.1068613-000	1.1015958-000	1.0947271-000	1.0922149-000	1.0880238-000

ABEL AREA MATRICES—AREA MATRIX

PAGE 5 ROWS 21-25

201	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
202	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
203	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
204	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
205	9.2895007+000	3.4544128+000	2.4448393+000	2.0588405+000	1.8325877+000
206	1.6851085+000	1.5803494+000	1.5018400+000	1.4404100+000	1.3914968+000
207	1.3512204+000	1.3174014+000	1.2591289+000	1.2447213+000	1.2435817+000
208	1.2251098+000	1.2088439+000	1.1944230+000	1.1815404+000	1.1700246+000
209	1.1594132+000	1.1502267+000	1.1416793+000	1.1338842+000	1.1267513+000
210	1.1202041+000	1.1141773+000	1.1084148+000	1.1034481+000	1.0984951+000
211	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
212	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
213	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
214	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
215	0.0000000-001	4.3918498+000	3.7349137+000	2.5164352+000	2.0993232+000
216	1.8663954+000	1.7143418+000	1.6062241+000	1.5250174+000	1.4616362+000
217	1.4107357+000	1.3689451+000	1.3340228+000	1.3044149+000	1.2790077+000
218	1.2564805+000	1.2377144+000	1.2207334+000	1.2054651+000	1.1922136+000
219	1.1801411+000	1.1642537+000	1.1593927+000	1.1504254+000	1.1422413+000
220	1.1347470+000	1.1278634+000	1.1215227+000	1.1154647+000	1.1102450+000
221	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
222	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
223	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
224	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
225	0.0000000-001	0.0000000-001	4.4919495+000	3.8176350+000	2.5673447+000
226	2.1390543+000	1.8994223+000	1.7431128+000	1.6316813+000	1.5478843+000
227	1.9824049+000	1.4297605+000	1.3864915+000	1.3502963+000	1.3195786+000
228	1.2931937+000	1.2702975+000	1.2502535+000	1.2325714+000	1.2168681+000
229	1.2028383+000	1.1902364+000	1.1788641+000	1.1685555+000	1.1591746+000
230	1.1504072+000	1.1427567+000	1.1355412+000	1.1288905+000	1.1227445+000
231	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
232	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
233	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
234	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
235	0.0000000-001	0.0000000-001	0.0000000-001	4.5898244+000	3.8946846+000
236	2.6171772+000	2.1780731+000	1.9322952+000	1.7714353+000	1.6567740+000
237	1.5704499+000	1.5029224+000	1.4485750+000	1.4038615+000	1.3664220+000
238	1.3346146+000	1.3072767+000	1.2835276+000	1.2627232+000	1.2443536+000
239	1.2280270+000	1.2134293+000	1.2003082+000	1.1884579+000	1.1777090+000
240	1.1679210+000	1.1589759+000	1.1537742+000	1.1432312+000	1.1362746+000
241	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
242	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
243	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
244	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
245	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	4.6854591+000
246	3.9741484+000	2.8660366+000	2.2164158+000	1.9444401+000	1.7993336+000
247	1.4815165+000	1.5927237+000	1.5231952+000	1.4671832+000	1.4210573+000
248	1.3824003+000	1.3495344+000	1.3212552+000	1.2944742+000	1.2751203+000
249	1.2566745+000	1.2391379+000	1.2239823+000	1.2103503+000	1.1980304+000
250	1.1868483+000	1.1746594+000	1.1673421+000	1.1567941+000	1.1509280+000

ABEL AREA MATRICES--AREA MATRIX

PAGE 6 ROWS 26-30

251	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
252	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
253	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
254	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
255	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
256	1.7795707+000	1.0501702+000	2.7140219+000	2.2541158+000	1.9940808+000
257	1.8248233+000	1.7059214+000	1.6147150+000	1.5432297+000	1.4855894+000
258	1.4380813+000	1.3983324+000	1.3643259+000	1.3351283+000	1.3097297+000
259	1.2874425+000	1.2677368+000	1.2501973+000	1.2349936+000	1.2203594+000
260	1.2075775+000	1.1959490+000	1.1853452+000	1.1757013+000	1.1668118+000
261	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
262	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
263	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
264	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
265	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
266	0.0000000-001	1.4716723+000	1.2477732+000	2.7611783+000	2.2912039+000
267	2.0272394+000	1.8539208+000	1.7300008+000	1.6344327+000	1.5430324+000
268	1.5037990+000	1.4549365+000	1.4139202+000	1.3789936+000	1.3488955+000
269	1.3226950+000	1.2946881+000	1.2793325+000	1.2612027+000	1.2449402+000
270	1.2303321+000	1.2172957+000	1.2050674+000	1.1940947+000	1.1840494+000
271	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
272	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
273	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
274	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
275	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
276	0.0000000-001	0.0000000-001	1.9620646+000	1.9805520+000	2.0075449+000
277	2.3277084+000	2.3579371+000	1.8804415+000	1.7537862+000	1.6578855+000
278	1.5824095+000	1.5218136+000	1.4716258+000	1.4299451+000	1.3935382+000
279	1.3625569+000	1.3355692+000	1.3118558+000	1.2908618+000	1.2721519+000
280	1.2553797+000	1.2402657+000	1.2265820+000	1.2141140+000	1.2027845+000
281	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
282	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
283	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
284	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
285	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
286	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
287	2.8531657+000	2.3636556+000	2.3881927+000	1.9070003+000	1.7772287+000
288	1.4790817+000	1.4019474+000	1.3396408+000	1.2841524+000	1.2448492+000
289	1.4079410+000	1.3741127+000	1.3483522+000	1.3239447+000	1.3022331+000
290	1.2839431+000	1.2657499+000	1.2501579+000	1.2360338+000	1.2231651+000
291	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
292	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
293	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
294	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
295	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
296	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
297	4.3409037+000	2.4980499+000	2.3497000+000	2.1180244+000	1.9330099+000
298	1.8003966+000	1.7002793+000	1.6211122+000	1.5572840+000	1.5045196+000
299	1.4601348+000	1.4222633+000	1.3895635+000	1.3610437+000	1.3359544+000
300	1.3137162+000	1.2938752+000	1.2760674+000	1.2600067+000	1.2454991+000

ABEL AREA MATRICES--AREA MATRIX

PAGE 7 ROWS 31-35

301	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
302	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
303	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
304	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
305	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
306	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
307	5.2239449-000	4.4105963-000	2.9422917-000	2.4339744-000	2.1474492-000
308	1.9584941-000	1.8232865-000	1.7207361-000	1.6400497-000	1.5747477-000
309	1.5207307-000	1.4752642-000	1.4364465-000	1.4029102-000	1.3736445-000
310	1.3478845-000	1.3250398-000	1.3046470-000	1.2863367-000	1.2698110-000
311	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
312	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
313	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
314	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
315	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
316	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
317	0.0000000-001	5.3082632-000	4.4792055-000	2.9859613-000	2.4483893-000
318	2.1764829-000	1.9840349-000	1.8459012-000	1.7412095-000	1.6587857-000
319	1.5920363-000	1.5367890-000	1.4902547-000	1.4505123-000	1.4161539-000
320	1.3861546-000	1.3597351-000	1.3362937-000	1.3153578-000	1.2965509-000
321	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
322	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
323	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
324	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
325	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
326	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
327	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
328	2.5023340-000	2.2051403-000	2.0070738-000	1.8482519-000	1.7414565-000
329	1.6773257-000	1.6091542-000	1.5524978-000	1.5051240-000	1.4644424-000
330	1.4292955-000	1.3985747-000	1.3715064-000	1.3474774-000	1.3260724-000
331	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
332	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
333	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
334	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
335	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
336	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
337	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
338	3.0711536-000	2.5358317-000	2.2334354-000	2.0338115-000	1.8903473-000
339	1.7814839-000	1.6956752-000	1.6261056-000	1.5684603-000	1.5198593-000
340	1.4782987-000	1.4423364-000	1.4109056-000	1.3831984-000	1.3585177-000
341	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
342	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
343	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
344	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
345	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
346	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
347	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
348	4.6799052-000	3.1129264-000	2.5688940-000	2.2613817-000	2.0582565-000
349	1.9121954-000	1.8012982-000	1.7138393-000	1.6428945-000	1.5840748-000
350	1.5344683-000	1.4420230-000	1.4552779-000	1.4231462-000	1.3948124-000

ABEL AREA MATRICES—AREA MATRIX

PAGE 8 ROWS 36-40

351	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
352	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
353	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
354	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
355	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
356	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
357	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
358	5.4332252+000	4.7437366+000	3.1541478+000	2.6015392+000	2.2889911+000
359	2.0824244+000	1.9338041+000	1.8209057+000	1.7318230+000	1.6595251+000
360	1.5995545+000	1.5489534+000	1.5054372+000	1.4681213+000	1.4353034+000
361	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
362	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
363	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
364	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
365	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
366	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
367	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
368	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
369	2.3142756+000	2.1063184+000	1.9551804+000	1.8403124+000	1.7496311+000
370	1.4767011+000	1.4149025+000	1.3633170+000	1.3191432+000	1.2808843+000
371	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
372	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
373	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
374	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
375	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
376	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
377	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
378	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
379	2.46654385+000	2.3432461+000	2.2299494+000	2.12743321+000	2.0355300+000
380	1.7472483+000	1.6923263+000	1.6301118+000	1.5775616+000	1.5325530+000
381	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
382	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
383	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
384	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
385	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
386	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
387	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
388	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
389	3.2747070+000	2.6971204+000	2.3699130+000	2.1533256+000	1.9972653+000
390	1.4785455+000	1.7847391+000	1.7085045+000	1.6451904+000	1.5916897+000
391	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
392	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
393	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
394	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
395	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
396	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
397	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
398	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
399	4.9942837+000	3.3139740+000	2.7282415+000	2.3962864+000	2.1745488+000
400	2.0179865+000	1.8972828+000	1.8020477+000	1.7245391+000	1.6601412+000

ABEL AREA MATRICES—AREA MATRIX

PAGE 9 ROWS 41-45

481	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
482	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
483	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
484	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
485	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
486	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
487	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
488	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
489	4.0147884+000	5.0549814+000	3.3524815+000	2.7590134+000	2.4223754+000
490	2.1993447+000	2.0385319+000	1.9140404+000	1.8191983+000	1.7404334+000
491	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
492	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
493	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
494	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
495	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
496	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
497	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
498	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
499	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
500	5.2900145+000	3.5034357+000	2.8788299+000	2.5240409+000	2.2884461+000

PAGE 10 ROWS 46-50

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ABEL AREA MATRICES--INVERSE MATRIX

PAGE 1 ROWS 1- 5

1	1.2732395-000	-1.1690219-000	1.7050417-001	-1.3705760-001	-4.2965059-003
2	-2.9678093-002	-1.2260344-002	-1.2204130-002	-8.5121852-003	-7.1433272-003
3	-5.7399987-003	-4.4211275-003	-4.0691575-003	-3.9926999-003	-3.0264345-003
4	-2.4490453-003	-2.3374205-003	-2.0782017-003	-1.3594345-003	-1.6738346-003
5	-1.5145436-003	-1.3769556-003	-1.2572978-003	-1.1525855-003	-1.0604294-003
6	-9.7889950-004	-9.0642275-004	-8.4170682-004	-7.8368197-004	-7.3145664-004
7	-6.8428293-004	-6.4152777-004	-6.0266162-004	-5.6722161-004	-5.3481817-004
8	-5.0511406-004	-4.7781757-004	-4.5267537-004	-4.2946659-004	-4.0799797-004
9	-3.8809979-004	-3.6942252-004	-3.5241405-004	-3.3641723-004	-3.2146795-004
10	-3.0799341-004	-2.9441768-004	-2.8214544-004	-2.7063100-004	-2.5980729-004
11	0.0000000-001	8.1408718-001	-7.0856510-001	1.0406641-001	9.0639149-002
12	-5.9025008-003	-2.1753615-002	-1.0134980-002	-9.7666249-003	-7.1020370-003
13	-5.9918133-003	-4.9034743-003	-4.1592971-003	-3.5485056-003	-3.0717584-003
14	-2.4825925-003	-2.3641334-003	-2.0989953-003	-1.8763174-003	-1.6873307-003
15	-1.5255936-003	-1.3860848-003	-1.2649078-003	-1.1589789-003	-1.0658702-003
16	-9.8350440-004	-9.1037466-004	-8.4511406-004	-7.8663525-004	-7.3402910-004
17	-6.84653405-004	-6.4350818-004	-6.0440740-004	-5.6876799-004	-5.3619282-004
18	-5.0634017-004	-4.7891467-004	-4.5366000-004	-4.3035280-004	-4.0879775-004
19	-3.8882343-004	-3.7027487-004	-3.5303075-004	-3.3696091-004	-3.2196437-004
20	-3.0794759-004	-2.9482702-004	-2.8252781-004	-2.7098275-004	-2.6013149-004
21	0.0000000-001	0.0000000-001	6.4568574-001	-5.5247599-001	8.4303094-002
22	-7.2458873-002	-4.8626627-002	-1.7881591-002	-4.5546519-003	-8.2864427-003
23	-6.1209033-003	-5.2093367-003	-4.3027464-003	-3.6771905-003	-3.1598032-003
24	-2.7523055-003	-2.44172732-003	-2.1411481-003	-1.9098678-003	-1.7144700-003
25	-1.5477516-003	-1.4043667-003	-1.2801227-003	-1.1717462-003	-1.0766329-003
26	-9.9269556-004	-9.1824265-004	-8.5189232-004	-7.9250625-004	-7.3913983-004
27	-6.9100378-004	-6.4734441-004	-6.0787034-004	-5.7183406-004	-5.3891732-004
28	-5.0876439-004	-4.8108758-004	-4.5560955-004	-4.3210698-004	-4.1038045-004
29	-3.9025510-004	-3.7157712-004	-3.5421077-004	-3.3803584-004	-3.2294570-004
30	-3.0884528-004	-2.9564479-004	-2.8328332-004	-2.7167777-004	-2.6077190-004
31	0.0000000-001	0.0000000-001	8.6736174-019	5.5149684-001	-4.6795740-001
32	7.3412978-002	-6.2002312-002	-3.9897793-003	-1.5445017-002	-7.4437442-003
33	-7.2465423-003	-5.4115435-003	-4.6335861-003	-3.8524330-003	-3.3102475-003
34	-2.8590499-003	-2.5018078-003	-2.2065955-003	-1.9621254-003	-1.7544503-003
35	-1.5819593-003	-1.4324477-003	-1.3034827-003	-1.1913051-003	-1.0931369-003
36	-1.0067194-003	-9.3023689-004	-8.6221192-004	-8.0143421-004	-7.4469352-004
37	-4.9778733-004	-4.5338403-004	-4.1311738-004	-3.7647447-004	-3.4303988-004
38	-5.1244278-004	-4.8437178-004	-4.5855467-004	-4.3755744-004	-4.1274925-004
39	-3.9291511-004	-3.7353511-004	-3.5693984-004	-3.3965402-004	-3.2442431-004
40	-3.1019748-004	-2.9688882-004	-2.8442079-004	-2.7272388-004	-2.6173565-004
41	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	4.6927332-001
42	-4.1313009-001	6.6097311-002	-5.5013343-002	-3.3483466-003	-1.3742009-002
43	-6.4284497-003	-6.5162403-003	-4.8755284-003	-4.1940667-003	-3.5023177-003
44	-3.0214343-003	-2.6194504-003	-2.3000885-003	-2.0352535-003	-1.8152183-003
45	-1.6275113-003	-1.4714936-003	-1.3357327-003	-1.2162303-003	-1.1157950-003
46	-1.0259287-003	-9.4663171-004	-8.7629179-004	-8.1359530-004	-7.5746309-004
47	-7.0700150-004	-6.6149513-004	-6.2022808-004	-5.8276152-004	-5.4861605-004
48	-5.1740773-004	-4.8880688-004	-4.6252908-004	-4.3832789-004	-4.1598663-004
49	-3.9532975-004	-3.7617124-004	-3.5838395-004	-3.4183530-004	-3.2641236-004
50	-3.1201487-004	-2.9855350-004	-2.8594849-004	-2.7412843-004	-2.6302923-004

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ABEL AREA MATRICES—INVERSE MATRIX

PAGE 2 ROWS 6-10

51	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
52	4.4429086-001	-3.7391210-001	4.0691203-002	-4.9929684-002	-2.8733927-003
53	-1.2472732-002	-6.0055526-003	-5.9388544-003	-4.4558943-003	-3.8464897-003
54	-3.2220747-003	-2.7880715-003	-2.4239248-003	-2.1340819-003	-1.8931223-003
55	-1.6924631-003	-1.5227193-003	-1.3779550-003	-1.2533296-003	-1.1452326-003
56	-1.0508075-003	-9.6780822-004	-8.9443412-004	-8.2923146-004	-7.7101382-004
57	-7.1880511-004	-6.7179582-004	-6.2930976-004	-5.9077826-004	-5.5572017-004
58	-5.2372603-004	-4.9444551-004	-4.6757738-004	-4.4286141-004	-4.2007183-004
59	-3.9901191-004	-3.7950942-004	-3.6141392-004	-3.4459177-004	-3.2892561-004
60	-3.1431121-004	-3.0065589-004	-2.8787704-004	-2.7590078-004	-2.6466091-004
61	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
62	0.0000000-001	4.0978827-001	-3.4407951-001	5.6464440-002	-4.6022848-002
63	-2.5127213-003	-1.1484285-002	-5.5136296-003	-5.4793734-003	-4.1179768-003
64	-3.5642805-003	-2.9924424-003	-2.5952270-003	-2.2612261-003	-1.9949895-003
65	-1.7732584-003	-1.5883132-003	-1.4315998-003	-1.2977294-003	-1.1822958-003
66	-1.0820130-003	-9.9427796-004	-9.1704283-004	-8.4664419-004	-7.8781399-004
67	-7.3340733-004	-6.8455080-004	-6.4050264-004	-6.0064266-004	-5.6444873-004
68	-5.3147863-004	-5.0135560-004	-4.7375700-004	-4.4840509-004	-4.2505972-004
69	-4.0351229-004	-3.8358089-004	-3.6510625-004	-3.4799843-004	-3.3198404-004
70	-3.1710394-004	-3.0321126-004	-2.9021983-004	-2.7805272-004	-2.6664111-004
71	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
72	0.0000000-001	0.0000000-001	3.8224917-001	-3.2040439-001	5.3033000-002
73	-4.2901703-002	-2.2317024-003	-1.0688389-002	-5.1147199-003	-5.1040252-003
74	-3.8395931-003	-3.3302196-003	-2.8006204-003	-2.4331748-003	-2.1236143-003
75	-1.8766740-003	-1.6707493-003	-1.4987924-003	-1.3529055-003	-1.2281324-003
76	-1.1204117-003	-1.0267159-003	-9.4464533-004	-8.7231127-004	-8.0819723-004
77	-7.5107704-004	-6.9994841-004	-6.5398543-004	-6.1250194-004	-5.7499280-004
78	-5.4076733-004	-5.0962256-004	-4.8113996-004	-4.5501987-004	-4.3100452-004
79	-4.0887030-004	-3.8942321-004	-3.6994362-004	-3.5193371-004	-3.3561235-004
80	-3.2041457-004	-3.0623842-004	-2.9299336-004	-2.8059875-004	-2.6898261-004
81	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
82	0.0000000-001	0.0000000-001	0.0000000-001	3.5940763-001	-3.0102493-001
83	5.0170459-002	-4.0335269-002	-2.0076583-003	-1.0031219-002	-4.7841595-003
84	-4.7989121-003	-3.8059224-003	-3.1326622-003	-2.4377916-003	-2.2949019-003
85	-2.0056020-003	-1.7747291-003	-1.5820248-003	-1.4209789-003	-1.2842256-003
86	-1.1471587-003	-1.0659475-003	-9.7792529-004	-9.0070857-004	-8.3258916-004
87	-7.1215500-004	-7.1824401-004	-6.6988229-004	-6.2639999-004	-5.8729723-004
88	-5.5171835-004	-5.1935188-004	-4.8981494-004	-4.6278095-004	-4.3796483-004
89	-4.1514020-004	-3.9408306-004	-3.7461662-004	-3.5658214-004	-3.3984045-004
90	-3.2426413-004	-3.0976006-004	-2.9621748-004	-2.8356432-004	-2.7170076-004
91	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
92	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	3.4056520-001
93	-2.8478238-001	4.7733379-002	-3.4177340-002	-1.8254498-003	-9.4775459-003
94	-4.5052976-003	-4.5251391-003	-3.4066974-003	-2.9634518-003	-2.4976863-003
95	-2.1754134-003	-1.9031937-003	-1.6659116-003	-1.5044301-003	-1.3526790-003
96	-1.2237333-003	-1.1132762-003	-1.0177597-003	-9.3454240-004	-8.6152906-004
97	-7.9707053-004	-7.3984211-004	-6.8877221-004	-6.4298443-004	-6.0175611-004
98	-5.6448448-004	-5.3067246-004	-4.9988989-004	-4.7177895-004	-4.4603259-004
99	-4.2234743-004	-4.0041634-004	-3.8052259-004	-3.6193502-004	-3.4477048-004
100	-3.2869642-004	-3.1380319-004	-2.9991580-004	-2.8694610-004	-2.7481375-004

ABEL AREA MATRICES--INVERSE MATRIX

PAGE 3 ROWS 11-15

101	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
102	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
103	3.2425933-001	-2.7091292-001	-4.5624104-002	-3.6330429-002	-1.6797054-003	-2.8167054-003
104	-9.0033501-003	-0.2665757-003	-0.2964294-003	-3.2345841-003	-1.4359511-003	-1.4359511-003
105	-2.3757261-003	-2.0710252-003	-1.8134122-003	-1.4077826-003	-8.9570196-004	-8.9570196-004
106	-1.2922178-003	-1.1700204-003	-1.0652998-003	-9.7468652-004	-6.1852962-004	-6.1852962-004
107	-0.2636304-004	-7.6511294-004	-7.1070109-004	-6.6211587-004	-4.5528519-004	-4.5528519-004
108	-5.7926059-004	-5.4374083-004	-5.1149536-004	-4.8212349-004	-3.5024554-004	-3.5024554-004
109	-4.3069028-004	-4.7808975-004	-3.9726882-004	-3.6804140-004	-2.7834289-004	-2.7834289-004
110	-3.3373968-004	-3.1839964-004	-3.3411808-004	-2.9079238-004	-2.0000000-001	-2.0000000-001
111	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
112	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
113	0.0000000-001	3.1009168-001	-2.5888999-001	-4.3774546-002	-3.4726409-002	-3.4726409-002
114	-1.5481339-003	-8.5916534-003	-4.054098-003	-4.0970891-003	-3.0842049-003	-3.0842049-003
115	-2.6880744-003	-2.2684005-003	-1.9789612-003	-1.7339945-003	-1.5384731-003	-1.5384731-003
116	-1.3750326-003	-1.2382409-003	-1.1219839-003	-1.0222765-003	-9.3597536-004	-9.3597536-004
117	-0.6071369-004	-7.9461374-004	-7.3619817-004	-6.8427999-004	-6.3789921-004	-6.3789921-004
118	-5.9627060-004	-5.5874665-004	-5.2788731-004	-4.9394600-004	-4.6583303-004	-4.6583303-004
119	-4.4014203-004	-4.1658246-004	-3.9492282-004	-3.7495913-004	-3.5651453-004	-3.5651453-004
120	-3.3941527-004	-3.2358468-004	-3.0865074-004	-2.9512347-004	-2.8231297-004	-2.8231297-004
121	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
122	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
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124	-3.3317048-002	-1.4404852-003	-8.2300932-003	-3.8778400-003	-3.6631901-003	-3.6631901-003
125	-2.9515274-003	-2.6742714-003	-2.1733731-003	-1.8970897-003	-1.6834721-003	-1.6834721-003
126	-1.4765275-003	-1.3204547-003	-1.1898474-003	-1.0787482-003	-9.8347213-004	-9.8347213-004
127	-9.0091746-004	-8.2902330-004	-7.6579717-004	-7.0990375-004	-6.6020862-004	-6.6020862-004
128	-4.1574647-004	-5.7591941-004	-5.3995964-004	-5.0740411-004	-4.7742293-004	-4.7742293-004
129	-4.5085353-004	-4.2616824-004	-4.0356425-004	-3.8275421-004	-3.6356755-004	-3.6356755-004
130	-3.9583566-004	-3.2940775-004	-3.1415746-004	-2.9997220-004	-2.8675268-004	-2.8675268-004
131	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
132	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
133	0.0000000-001	0.0000000-001	0.0000000-001	2.8654354-001	-2.3897773-001	-2.3897773-001
134	4.0668115-002	-3.2045583-002	-1.3478967-003	-7.9094371-003	-3.7171440-003	-3.7171440-003
135	-3.7656339-003	-2.4334674-003	-2.4727671-003	-2.0883524-003	-1.8237473-003	-1.8237473-003
136	-1.5996236-003	-1.4207950-003	-1.2712478-003	-1.1460906-003	-1.0394092-003	-1.0394092-003
137	-9.4827622-004	-8.6918235-004	-8.0016709-004	-7.3951632-004	-6.8538187-004	-6.8538187-004
138	-6.3819100-004	-5.9553404-004	-5.5723685-004	-5.2268692-004	-4.9139723-004	-4.9139723-004
139	-4.6275651-004	-4.3701790-004	-4.1328701-004	-3.9151253-004	-3.7149872-004	-3.7149872-004
140	-3.5299945-004	-3.3591333-004	-3.2008003-004	-3.0537656-004	-2.9149515-004	-2.9149515-004
141	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
142	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
143	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
144	-2.3064224-001	-3.9345458-002	-3.0944803-002	-1.2674706-003	-7.6226421-003	-7.6226421-003
145	-3.5737481-003	-3.6260003-003	-2.7276265-003	-2.3815626-003	-2.0118375-003	-2.0118375-003
146	-1.7576162-003	-1.5421996-003	-1.3703541-003	-1.2244311-003	-1.1043496-003	-1.1043496-003
147	-1.0039944-003	-9.1619433-004	-8.4914774-004	-7.7377943-004	-7.1544296-004	-7.1544296-004
148	-6.6384370-004	-6.1794202-004	-5.7689724-004	-5.4002189-004	-5.0674914-004	-5.0674914-004
149	-4.7660773-004	-4.4920291-004	-4.2420181-004	-4.0132190-004	-3.8032197-004	-3.8032197-004
150	-3.4097498-004	-3.4316230-004	-3.2666907-004	-3.1138045-004	-2.9717853-004	-2.9717853-004

ABEL AREA MATRICES--INVERSE MATRIX

PAGE 4 ROWS 16-20

151	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
152	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
153	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
154	2.6748880-001	-2.2304772-001	3.8144684-002	-2.9933495-002	-1.1969952-003
155	-7.3642344-003	-3.4448606-003	-3.5000985-003	-2.6321090-003	-2.2991467-003
156	-1.9425573-003	-1.6976395-003	-1.4900347-003	-1.3244581-003	-1.1857689-003
157	-1.0700427-003	-9.7143377-004	-8.8681867-004	-8.1352242-004	-7.4954593-004
158	-6.9330320-004	-6.4354740-004	-5.927738-004	-5.5966370-004	-5.2410454-004
159	-4.919424-004	-4.6289913-004	-4.3643943-004	-4.1229462-004	-3.9019284-004
160	-3.6990196-004	-3.5122275-004	-3.3398329-004	-3.1803455-004	-3.0324676-004
161	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
162	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
163	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
164	0.0000000-001	2.5955019-001	-2.1619363-001	3.7048040-002	-2.9014978-002
165	-1.1347558-003	-7.1298910-003	-3.3262686-003	-3.3858798-003	-2.5453779-003
166	-2.2211959-003	-1.8794853-003	-1.6429570-003	-1.4424088-003	-1.2824955-003
167	-1.1487387-003	-1.0367967-003	-9.4153773-004	-8.5480999-004	-7.8009533-004
168	-7.2725548-004	-6.7295677-004	-6.2478894-004	-5.8200570-004	-5.4373568-004
169	-5.0934010-004	-4.7829238-004	-4.5015478-004	-4.2456072-004	-4.03120109-004
170	-3.7981355-004	-3.6017413-004	-3.4269075-004	-3.2519744-004	-3.0995047-004
171	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
172	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
173	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
174	0.0000000-001	0.0000000-001	2.5211144-001	-2.0993316-001	3.6004128-002
175	-2.8175908-002	-1.0794747-003	-6.7161471-003	-3.2221942-003	-3.2816915-003
176	-2.6642640-003	-2.1557021-003	-1.8217826-003	-1.5928708-003	-1.3987285-003
177	-1.2439608-003	-1.1145068-003	-1.0261714-003	-9.1398060-004	-8.3488374-004
178	-7.6635926-004	-7.0653841-004	-6.5393849-004	-6.0739513-004	-5.6597253-004
179	-5.2891500-004	-4.9540463-004	-4.6553208-004	-4.3827400-004	-4.1347589-004
180	-3.7083485-004	-3.7010724-004	-3.5107063-004	-3.3353690-004	-3.1734803-004
181	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
182	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
183	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
184	0.0000000-001	0.0000000-001	0.0000000-001	2.4527773-001	-2.0418679-001
185	3.5112672-002	-2.7405440-002	-1.0298687-003	-6.7201921-003	-3.1251927-003
186	-3.1861449-003	-2.3737002-003	-2.0929203-003	-1.7687571-003	-1.5467920-003
187	-1.3585008-003	-1.2084325-003	-1.0629101-003	-9.7787203-004	-8.8848804-004
188	-8.1179491-004	-7.4535993-004	-6.8735691-004	-6.3635273-004	-5.9121781-004
189	-5.5104547-004	-5.1510296-004	-4.8279136-004	-4.5361706-004	-4.2716979-004
190	-4.0310607-004	-3.8113628-004	-3.6101470-004	-3.4253157-004	-3.2550884-004
191	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
192	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
193	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
194	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	2.3897117-001
195	-1.9888780-001	3.4252570-002	-2.6694837-002	-9.8528375-004	-6.5397190-003
196	-3.0360770-003	-3.0982475-003	-2.3268733-003	-2.0348492-003	-1.7198323-003
197	-1.5042336-003	-1.3213125-003	-1.1755559-003	-1.0536427-003	-9.5163249-004
198	-8.6482737-004	-7.9035276-004	-7.2583093-004	-6.6950105-004	-6.1996637-004
199	-5.7612769-004	-5.3711042-004	-5.0219699-004	-4.7080786-004	-4.4246378-004
200	-4.1674647-004	-3.9338252-004	-3.7203082-004	-3.5247289-004	-3.3450516-004

ABEL AREA MATRICES—INVERSE MATRIX

PAGE 5 ROWS 21-25

201	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
202	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
203	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
204	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
205	2.3312737-C01	-1.4398102-C01	3.3452922-C02	-2.6036640-C02	-9.4444444-C04
206	-6.3729155-C03	-2.9538627-C03	-3.0169537-C03	-2.2650879-C03	-1.9812014-C03
207	-1.6745241-C03	-1.4647714-C03	-1.2868147-C03	-1.1450309-C03	-1.0244444-C03
208	-9.2722616-C04	-8.4279947-C04	-7.7036840-C04	-7.0761726-C04	-6.5281305-C04
209	-6.0465667-C04	-5.6202079-C04	-5.2406852-C04	-4.9010804-C04	-4.5957367-C04
210	-4.3199937-C04	-4.0699789-C04	-3.8424506-C04	-3.6346740-C04	-3.4443367-C04
211	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
212	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
213	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
214	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
215	0.0000000-C01	2.2769231-C01	-1.8942033-C01	3.2706940-C02	-2.5424752-C02
216	-9.0829566-C04	-6.2178814-C03	-2.8777258-C03	-2.9415260-C03	-2.2077586-C03
217	-1.9313816-C03	-1.6324232-C03	-1.4281117-C03	-1.2547105-C03	-1.1166015-C03
218	-1.0010431-C03	-9.2445879-C04	-8.2234884-C04	-7.5169566-C04	-6.9058151-C04
219	-6.3723337-C04	-5.9031705-C04	-5.4679521-C04	-5.1183370-C04	-4.7875840-C04
220	-4.9901849-C04	-4.2216702-C04	-3.9780600-C04	-3.7544074-C04	-3.5539826-C04
221	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
222	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
223	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
224	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
225	0.0000000-C01	0.0000000-C01	2.2262049-C01	-1.8516687-C01	3.2008864-C02
226	-2.9853994-C02	-8.7480663-C04	-6.0735665-C03	-2.8069714-C03	-2.6713069-C03
227	-2.1543498-C03	-1.4849687-C03	-1.5931806-C03	-1.3938994-C03	-1.2247459-C03
228	-1.0900481-C03	-9.7739771-C04	-8.8316297-C04	-8.0298486-C04	-7.3420397-C04
229	-6.7461850-C04	-6.2254941-C04	-5.7685444-C04	-5.3634971-C04	-5.0033064-C04
230	-4.6807994-C04	-4.3908745-C04	-4.1288957-C04	-3.8913964-C04	-3.6752292-C04
231	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
232	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
233	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
234	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
235	0.0000000-C01	0.0000000-C01	0.0000000-C01	2.1787317-C01	-1.8118763-C01
236	3.1353742-C02	-2.4319762-C02	-8.4412525-C04	-5.9387232-C03	-2.7410092-C03
237	-2.8057358-C03	-2.1045572-C03	-1.8416325-C03	-1.5564974-C03	-1.3619992-C03
238	-1.1947021-C03	-1.0651812-C03	-9.5519240-C04	-8.6319361-C04	-7.8492181-C04
239	-7.1777976-C04	-6.5461610-C04	-6.0883959-C04	-5.6418815-C04	-5.2467099-C04
240	-4.8949320-C04	-4.5401279-C04	-4.2970522-C04	-4.0413845-C04	-3.8095355-C04
241	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
242	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
243	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
244	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01
245	0.0000000-C01	0.0000000-C01	0.0000000-C01	0.0000000-C01	2.1341715-C01
246	-1.7745437-C01	3.0737390-C02	-2.3818885-C02	-8.1590037-C04	-5.8123697-C03
247	-2.6779330-C03	-2.7443320-C03	-2.0578972-C03	-1.8009729-C03	-1.5221154-C03
248	-1.3318906-C03	-1.1703897-C03	-1.0418343-C03	-9.3433500-C04	-8.4442433-C04
249	-7.6773396-C04	-7.0232368-C04	-6.4548929-C04	-5.9587480-C04	-5.5224612-C04
250	-5.1363456-C04	-4.7926302-C04	-4.4850391-C04	-4.2084455-C04	-3.9586269-C04

ABSL AREA MATRICES—INVERSE MATRIX

PAGE 6 ROWS 26-30

251	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
252	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
253	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
254	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
255	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
256	2.892231-001	-1.7394274-001	3.0154068-002	-2.3347511-002	-7.8984727-004
257	-5.4936544-003	-2.4215113-003	-2.4884807-003	-2.0140951-003	-1.7628113-003
258	-1.8898109-003	-1.3034819-003	-1.1456438-003	-1.0198699-003	-9.1449849-004
259	-8.2674452-004	-7.5192331-004	-6.8774851-004	-6.3216003-004	-5.8343502-004
260	-5.4094548-004	-5.0320342-004	-4.6458841-004	-4.3950436-004	-4.1245568-004
261	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
262	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
263	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
264	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
265	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
266	0.0000000-001	2.0524732-001	-1.7063165-001	2.9406588-002	-2.2903021-002
267	-7.4572323-004	-5.5818525-003	-2.5671638-003	-2.6324215-003	-1.9728778-003
268	-1.7268840-003	-1.4593890-003	-1.2771057-003	-1.1223202-003	-9.9915655-004
269	-8.9617320-004	-8.1005497-004	-7.3680360-004	-6.7397731-004	-6.1955956-004
270	-5.7205832-004	-5.3029733-004	-4.9332699-004	-4.6042346-004	-4.3097833-004
271	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
272	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
273	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
274	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
275	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
276	0.0000000-001	0.0000000-001	2.0152902-001	-1.6750271-001	2.9086142-002
277	-2.2482956-002	-7.4332719-004	-5.4763178-003	-2.5159646-003	-2.5812407-003
278	-1.9340064-003	-1.6929868-003	-1.4306786-003	-1.2520152-003	-1.1002920-003
279	-9.7958557-004	-8.7866208-004	-7.9427587-004	-7.2249856-004	-6.6099199-004
280	-6.0762465-004	-5.4108969-004	-5.2017099-004	-4.8394022-004	-4.5172720-004
281	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
282	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
283	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
284	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
285	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
286	0.0000000-001	0.0000000-001	0.0000000-001	1.9798489-001	-1.6453982-001
287	2.8592254-002	-2.2085160-002	-7.2245874-004	-5.3744916-003	-2.4676270-003
288	-2.5324626-003	-1.8972718-003	-1.6409399-003	-1.4035297-003	-1.2282811-003
289	-1.0794477-003	-9.6105929-004	-8.6207917-004	-7.7932516-004	-7.0894053-004
290	-6.4858202-004	-5.7630700-004	-5.5048012-004	-5.1054310-004	-4.7506283-004
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292	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
293	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
294	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
295	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
296	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	1.9442521-001
297	-1.4172878-001	2.8122737-002	-2.1707735-002	-7.0298345-004	-5.2818816-003
298	-2.4218499-003	-2.4870444-003	-1.8424891-003	-1.6305849-003	-1.3778092-003
299	-1.2057889-003	-1.0594880-003	-9.4349108-004	-8.4634822-004	-7.6513724-004
300	-6.9406924-004	-6.3684344-004	-5.8555208-004	-5.4078580-004	-5.0142699-004

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PAGE 7 ROWS 31-35

301	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
302	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
303	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
304	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
305	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
306	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
307	1.9122915-001	-1.5905705-001	2.7675647-002	-2.1349001-002	-6.8475901-004	-1.4017814-003
308	-5.1925519-003	-2.3785582-003	-2.4435774-003	-1.8294952-003	-1.4017814-003	-1.4017814-003
309	-1.3533994-003	-1.1844370-003	-1.0409249-003	-9.2630381-004	-8.3140122-004	-5.3136744-004
310	-7.5165175-004	-8.8383084-004	-6.2567797-004	-5.7531841-004	-5.3136744-004	-5.3136744-004
311	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
312	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
313	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
314	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
315	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
316	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
317	0.0000000-001	1.4838554-001	-1.5651150-001	2.7249252-002	-2.1007466-002	-1.7981449-003
318	-6.5746707-004	-5.1066154-004	-2.3374077-003	-2.4022554-003	-1.7981449-003	-1.7981449-003
319	-1.5744044-004	-1.3301955-004	-1.1641348-004	-1.0230799-004	-9.1092856-004	-5.6556495-004
320	-6.1717735-004	-7.3681446-004	-6.7217708-004	-6.1504230-004	-5.6556495-004	-5.6556495-004
321	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
322	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
323	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
324	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
325	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
326	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
327	0.0000000-001	0.0000000-001	1.6548263-001	-1.5409819-001	2.6842000-002	-2.3629240-003
328	-2.0481779-002	-6.5160371-004	-5.0252292-003	-2.2982720-003	-2.3629240-003	-2.3629240-003
329	-1.7483087-003	-1.5483425-003	-1.3081036-003	-1.1448013-003	-1.0040826-003	-6.0489742-004
330	-8.9580358-004	-8.0362205-004	-7.2657742-004	-6.6106456-004	-6.0489742-004	-6.0489742-004
331	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
332	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
333	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
334	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
335	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
336	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
337	0.0000000-001	0.0000000-001	0.0000000-001	1.8270992-001	-1.5177224-001	-2.2609947-003
338	2.6452500-002	-2.0375810-002	-6.3647730-004	-4.9475836-003	-2.2609947-003	-1.1253249-003
339	-2.3254263-003	-1.7398711-003	-1.5234958-003	-1.2870399-003	-1.1253249-003	-6.5045514-004
340	-9.8869776-004	-8.8137337-004	-7.9068623-004	-7.1484635-004	-6.5045514-004	-6.5045514-004
341	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
342	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
343	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
344	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
345	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
346	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
347	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	1.8005795-001
348	-1.4955768-001	2.6079496-002	-2.3073429-002	-6.2220674-004	-4.8734028-003	-1.2669287-003
349	-2.2254356-003	-2.2842611-003	-1.7127279-003	-1.4997747-003	-1.2669287-003	-1.2669287-003
350	-1.1087571-003	-9.7438460-004	-8.6758789-004	-7.7632557-004	-7.0373196-004	-7.0373196-004

ABEL AREA MATRICES--INVERSE MATRIX

PAGE 8 ROWS 36-40

351	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
352	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
353	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
354	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
355	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
356	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
357	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
358	1.7751820-001	-1.4743730-001	2.5721855-002	-1.9788492-002	-4.0872007-004
359	-4.8024382-003	-2.1914687-003	-2.2554009-003	-1.6867857-003	-1.4770982-003
360	-1.2477020-003	-1.0919218-003	-9.5957567-004	-8.5440187-004	-7.4469994-004
361	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
362	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
363	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
364	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
365	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
366	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
367	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
368	0.0000000-001	1.7508298-001	-1.4540462-001	2.5378547-002	-1.9515729-002
369	-5.9553084-004	-4.7344457-003	-2.1584803-003	-2.2224399-003	-1.6619599-003
370	-1.4553934-003	-1.2292983-003	-1.2752048-003	-9.4539442-004	-8.4177433-004
371	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
372	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
373	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
374	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
375	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
376	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
377	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
378	0.0000000-001	0.0000000-001	1.7274530-001	-1.4345376-001	2.5046645-002
379	-1.9253751-002	-5.8344643-004	-4.4492302-003	-2.1278477-003	-2.1912429-003
380	-1.4381791-003	-1.4345741-003	-1.2114415-003	-1.0403574-003	-9.3180459-004
381	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
382	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
383	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
384	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
385	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
386	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
387	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
388	0.0000000-001	0.0000000-001	0.0000000-001	1.7049883-001	-1.4157937-001
389	2.4731291-002	-1.9002040-002	-5.7235471-004	-4.4064990-003	-2.0930379-003
390	-2.1611190-003	-1.6153568-003	-1.4144401-003	-1.1947411-003	-1.0455357-003
391	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
392	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
393	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
394	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
395	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
396	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
397	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
398	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	1.6833778-001
399	-1.3977658-001	2.4425712-002	-1.8759943-002	-5.6142568-004	-4.545536-003
400	-2.0694063-003	-2.1321855-003	-1.5934508-003	-1.3954767-003	-1.1784907-003

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PAGE 9 ROWS 41-45

401	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
402	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
403	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
404	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
405	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
406	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
407	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
408	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
409	1.4425484-001	-1.3804095-001	2.4131194-002	-1.8524845-002	-5.5101968-004
410	-4.4884704-003	-2.0418758-003	-2.1073388-003	-1.5723927-003	-1.3775338-003
411	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
412	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
413	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
414	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
415	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
416	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
417	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
418	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
419	0.0000000-001	1.4425123-001	-1.3436841-001	2.3470911-002	-1.8302258-002
420	-5.4109904-004	-4.4329700-003	-2.0154361-003	-2.0775939-003	-1.5552130-003
421	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
422	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
423	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
424	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
425	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
426	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
427	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
428	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
429	0.0000000-001	0.0000000-001	1.44231454-001	-1.3475523-001	-2.3572797-002
430	-1.8085422-002	-5.3142944-004	-4.3792633-003	-1.9899427-003	-2.0518037-003
431	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
432	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
433	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
434	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
435	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
436	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
437	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
438	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
439	0.0000000-001	0.0000000-001	0.0000000-001	1.4048644-001	-1.3319797-001
440	2.3307762-002	-1.7876497-002	-5.2258047-004	-4.3275526-003	-1.9654145-003
441	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
442	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
443	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
444	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
445	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
446	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
447	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
448	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001
449	0.0000000-001	0.0000000-001	0.0000000-001	0.0000000-001	1.5844375-001
450	-1.3169348-001	2.3051475-002	-1.7674459-002	-5.1392333-004	-4.2774294-003

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[illegible]

J. Concerning passwords

When this documentation was written, batch passwords were not needed on the 1110 computer. As of October 1, 1976, such passwords were required. Thus in addition to the cards described to run AMXINV2, somewhere in the deck a card stating

@PASS word

must be inserted, where "word" is the individual user's password. A password card is found in the program deck in the card file immediately following the @RUN card.

II. Loading Abel Area Matrices onto Mass (File) Storage

In order for the remaining programs in the Abel package to be able to use the Abel Area Matrices, they must be resident on the computer's mass storage system. This section tells (1) how to determine if the matrices are present on the computer's disk system (mass file storage device) and (2) how to put them there if they are not already.

A. Are the matrices on file?

Get on line for an interactive run using UWGT, UWLG, or UMTT, followed by an @RUN statement and a password. After successfully giving your password and receiving the prompt

CONTINUE

enter the following statement:

```
@ASG,A ABEL*DATA
```

This will attempt to assign the file containing the matrices to the run. If the file is present, the response

READY

will be printed, and the rest of this section may be skipped. If the response:

FACILITY REJECTED 400010000000

is given, that means that the file ABEL*DATA does not exist and must be created using the procedures in the next paragraph.

B. How to load matrices onto the disk

A card deck with the Abel Matrices and the proper control cards (except for the @RUN, @PASS, and @FIN cards) is on file in the group's computer card file. If a fresh deck of the matrices has been punched using AMXINV2, the control cards will have to be punched by the user. First the procedure will be given, then the control cards will be explained. The @RUN card in the example would be correct for the author--other users should substitute their own initials and user ID number where appropriate.

The full card deck to load the matrices is as follows:

```
@RUN AS,2231,1893602639,$5.00
@DELETE,C ABEL*DATA.
@ASG,UP ABEL*DATA.
@SAVE,S ABEL*DATA.
@DATA,I ABEL*DATA.
```

1000 data cards with the Abel Area and Inverse Area Matrices


```
@END  
@FREE ABEL*DATA  
@FIN
```

Obviously, this cannot be done as an interactive run but must be run batch. The data cards must be in order and must not contain any extraneous cards. An @PASS card is also needed in the deck.

The @RUN card starts the run and tells the computer who to bill (the \$5.00 limits the cost of the run, should something go wrong). @DELETE,C wipes out the old version of the file if it's present or simply prints an error message and continues if the file is not present (this way the same procedure can be used for making the file fresh and correcting errors). @ASG,UP recreates the file, albeit without any contents. @SAVE,S saves the file i.e. preserves for use on future days (otherwise the file would disappear at 4:30 A.M. when computer operations terminate). @DATA,I tells the computer that what follows is the data to be loaded into the file. @END signals the end of the data, and @FREE releases the file to be stored on the disk. Finally, @FIN terminates the run. The file name ABEL*DATA must be used for compatibility with all other programs.

[illegible]

```
BRUN AS,2231,1893602639,55.00
DELETE,C ABEL=DATA.
EUSPUB-HACC-2-02-07414-17:58
```

ABEL-DATA IS NOT CATALOGUED OR ASSIGNED
EAC STATUS: 400010000000

```

GAS6,UP ABEL=DATA.
GSAVE,S ABEL=DATA.

```

MACC SAVE PROFESSOR VERSION 5.0611

```
ABEL=DATA(1) TO BE SAVED INDEFINITELY
END SAVE...
```

DATA, LABEL=DATA
DATA01- 07/14-17:58:08

~~END DATA. IMAGE COUNT= 1000~~

```
END DATA IMAGE
&FREE ABEL=DATA.
&FIN
```

AFIM

FILE LOAD
OUTPUT

RUNID: DD0248 PROJECT: 02231 USER: 1893602639

ITEM	AMOUNT	COST(DOLLARS)
CPU TIME	00:00:00.291	\$0.01
FILE I/O REQUESTS	80	\$0.03
FILE I/O WORDS	24170	\$0.01
SWAP REQUESTS	2	\$0.00
SWAP WORDS	2048	\$0.00
MEMORY USAGE	0.021	\$0.01
CARDS IN	1008	\$1.01
PAGES PRINTED	1	\$0.01
ER + CC	8	\$0.07
JOB CHARGE	1	\$0.16
TOTAL COST		\$1.31

~~THE ABOVE DOLLAR AMOUNTS ARE APPROXIMATE AND ARE BASED ON RATES~~

INITIATION TIME: 17:58:04-JUL 14, 1975 FOR OVERNIGHT RUNS

TERMINATION TIME: 17:58:14-JUL 14, 1975

PREVIOUS RUN TIME: 10:48:58-JUL 13, 1975

... 123456789012 1 PAGES COST .. 10.03 34567890123456789012345678901234567890
1234567890123456789012345678901234567890123456789012345678901234567890
1234567890123456789012345678901234567890123456789012345678901234567890
1234567890123456789012345678901234567890123456789012345678901234567890

III. Program ABELMATCHK

A. Purpose

ABELMATCHK is used to determine if the Abel Area Matrices are properly on file. If errors are found, the output gives some indication as to where the problem lies. If the program produces no diagnostics, one can rest assured that the Abel Matrices are correctly filed in a form suitable for use with the Abel Inversion modeling programs.

ABELMATCHK (ABEL area MATrix CHecKout program) may be used either in batch mode or interactively. Input parameters allow the program either to operate under predetermined default conditions or under novel conditions as determined by the user.

B. Preparation for use

To be able to run the program, two steps must have been completed: (1) The Abel Area Matrices must be on file, as described in Section II of this documentation and (2) ABELMATCHK must be on file CHEMISTRY*WALTERS. One gets to the point of initiating the program by saying (after the @RUN card or statement):

```
@BASIC CHEMISTRY*WALTERS.  
OLD:ABELMATCHK  
RUN
```

(or RUNNH)

(//01 is unnecessary--the file
will not be written on)

It should be noted that when the program is through and it is desired that the computer be shut down, the statements to do that (since the program should terminate while still in BASIC) are:

```
BYE
@FIN      (or, for a more detailed billing on an interactive run,
           @FIN,C)
```

C. Program method of operation

The Abel matrices are checked for accuracy by determining if the reputed Area Matrix is indeed the inverse of the Inverse Area Matrix. If cards get "shuffled" in loading the matrices or there are punching errors, the product of the area and inverse matrices will be incorrect, and the errors will occur in recognizable patterns. Thus the steps in the program are: (1) input the area and inverse matrices; (2) multiply the two matrices together and (3) check that the product matrix is the identity matrix to within predetermined limits (preferably to within round-off error).

D. Input to program

The user must specify two items to ABELMATCHK: (1) the name of the file containing the area matrices and (2) the limits within which the product of the two matrices must equal the identity matrix. Default values exist for both specifications.

With regard to the defaults: Entering either the digit 0 or the number -2 when a question is asked by ABELMATCHK will result in default values being used. The default file containing the matrices is ABEL*DATA (conveniently the file name illustrated in preceding sections) and the default error limit is $5.0 \cdot 10^{-8}$, a value found by trial and observation to be suitable. If default values are entered in response to questions and the matrices are properly on file, one should receive no diagnostics and further, may rest assured that adequate checks have been performed in searching for matrix errors. In the absence of due cause, use of the default values is recommended.

The first question that the program asks is:

WHAT IS THE NAME OF THE INPUT DATA FILE?

As noted above, the answer "0" or "-2" will result in the use of ABEL*DATA as the input file. However, some user may have placed the matrices into a file with a different name, say ABEL*EXAMPLE. That file name, including the asterisk where appropriate, would then be entered in response to the above question. Whether a period follows the file name is immaterial; the program sets syntax automatically. Note that typing "ABEL*DATA" is equivalent to entering a 0 or -2. If you assign an improper file, program operation will terminate and in all likelihood control will rest

with the computer operating system, not with BASIC. To recover from such an error, enter a new @BASIC CHEMISTRY*WALTERS. statement and try again. Be SURE that ABEL*DATA or some other data file exists before attempting to run ABELMATCHK! The procedure for checking file existence is in II.A above.

Once the matrices have successfully been recovered from the file, they are multiplied together, and the following question is asked of the user:

WHAT IS ALLOWABLE MATRIX ERROR?

Recall that for the identity matrix, all elements along the diagonal of the matrix (matrix C(I,J)'s diagonal elements are those elements for which $I=J$) should equal 1.000... and all other elements should equal 0.000.... The allowable error is the amount the individual elements of the product matrix may differ from their theoretically desired values. As the area and inverse matrix contain transcendental numbers, some round-off error is unavoidable. Using matrices known to be accurate, it was determined that the maximum error to be expected due to round-off was approximately $4.74 \cdot 10^{-8}$ anywhere in the matrix (see sample output attached). As BASIC retains only seven and one-half significant figures, it can be seen that this is indeed round-off and not some other systematic error. Correspondingly, the default value for the

allowable matrix error has been set to $5.0 \cdot 10^{-8}$. Use of a smaller value is needlessly restrictive and causes excessive diagnostic printouts; use of larger value might allow some errors to slip through. If an error limit less than or equal to zero is specified, then the default limit is employed; any positive limit, no matter how close to zero, is used as entered as the maximum error limit. The default limit is highly recommended for standard use.

E. Interpretation of output

After the maximum allowable matrix error is specified, the program searches systematically through the product matrix for entries which are not within the allowable error limit. If it finds an erroneous value, an error printout is generated:

I=5 J=17 C(I,J)= $4.85 \cdot 10^{-5}$

Here I is the row of the area matrix used in calculating C(I,J) and J is the column of the inverse area matrix used in the calculation. C(I,J) is what the product of the row and column actually were; if $I=J$ then C(I,J) should equal 1.000..., otherwise it should equal 0.000.... Using these error printouts for uncovering precisely where the matrices are in error will be discussed shortly.

When the entire product matrix has been searched for erroneous values, the following message is printed:

IF NO ERROR PRINTOUTS HAVE BEEN PRINTED
THE MATRICES ARE CORRECTLY ON FILE.
OTHERWISE CHECK FOR PUNCH ERRORS.

If the matrices are filed correctly, there should not be any error printouts as given on the previous page. If this is the case, the matrices are ready for use. If error printouts did occur, however, the pattern of I and J values where the errors were found can be instrumental in finding which matrix elements are incorrectly filed and can thus speed debugging. If the error exists on the file (i.e. on searching the cards no mispunches or "card shuffles" are found), the file may simply be reloaded using the procedure given in Section II. If an error is found in the cards, these may be corrected, based on the output listing from program AMXINV2. If large numbers of cards are mispunched, or if the cards are getting dog-eared with use, AMXINV2 may be rerun. Note: The correct form for a number to be read by BASIS is 1.2345678E+03. The listing from AMXINV2 (but NOT the punched cards) is in the form 1.2345678+003. Do not let this confuse either you or the computer.

Possible error printout patterns are as follows:

(1) The default error limit was not used, and large numbers of error printouts are obtained, with the I and J values

scattered throughout the matrix in no discernible pattern. In this case the error limit chosen was too small, and the program should be rerun with a larger error limit.

(2) If the default error limit was used and either large numbers of error printouts are obtained or there are errors in attempting to input the area matrices, another computer user may have overwritten the data file. Additionally, if nonstandard procedures have been used, the wrong file may have been accessed. In either case, determine (with MACC consulting help if necessary) the cause of the problem. Reload the file according to the procedures of Section II if appropriate.

(3) A number of error printouts appear, but all have the same I value. In this case, row I of the area matrix has been entered incorrectly. Search the card deck for the appropriate row (the AMXINV2 printout will be helpful for this) and determine if any cards got shuffled, cards have been mispunched, damaged, etc. Correct the errors and do a complete file reload.

(4) A number of error printouts appear, but all have the same J value. In this case, column J of the inverse area matrix has in some manner been incorrectly entered. As in the case of (3), search the deck for the source of the problem. Sorting through punched cards looking for all elements of a given column is not an easy task; it may be easier to obtain a fresh punching from AMXINV2.

Notice that in all cases where real errors are encountered it is recommended that the entire file be reloaded. MACC has software which allows correction of specific elements of a file, but it is the author's opinion that a total file reload is vastly easier to accomplish than to track down and edit a single record within a file.

Two convenient ways exist for getting listings of decks. When MACC is not crowded, the deck verifier in the Basic Machines Room can be used for listing decks. At all times, the OFFLINE listing facility may be employed. A brief, pamphlet, available at MACC, details the use of this free, convenient facility.

F. Variable list

There follows a listing of the variables used in ABELMATCHK and the purposes for which they are employed. This may prove helpful should modification of the program be desired.

Variable	Meaning
A(50,50)	Abel Area Matrix
B(50,50)	Inverse Abel Area Matrix
C(50,50)	Matrix product of A and B
D(5)	Input buffer to transfer matrices from the input file to the A and B arrays
I	Row index for the Area Matrix; row index for matrix being input

J	Column index for Inverse Area Matrix; index to which group of five columns the data in the D array should be placed.
K, K1, K2, K3	Auxiliary indices used during input of matrices
Q	Allowable product matrix error limit
XS	Name of file containing matrices
AS	Alphanumeric period (.); used to determine syntax of XS and ZS
ZS	@USE command to access matrices in a form compatible with BASIC

G. Modification possibilities

Depending on the user's predilections, two modifications of the file selection procedure may be desired. First, the flexibility as to the name of the input file may be superfluous; if only one set of Abel Area Matrices i.e. one discharge geometry is to be considered at any given time, then the file name ABEL*DATA might be "hard-wired" into the program and the question as to the file name deleted. The second possibility is to modify the program to accept input directly from punched cards. As the program stands, one must create a file with the matrices in that file before the program is usable. There may be instances where one wishes to check a card deck that this convention would be clumsy. While the author has never had cause to check a card deck directly, this extra check-out step may be found desirable by other users. It should be noted that if one finds an error in

the file immediately after loading the file, the cause of the problem is in the card deck, not in the file.

H. Program listing and sample output

Appended will be found a listing of ABELMATCHK, and two sample runs, one with the default matrix error limit, and the other with an error limit that is slightly too restrictive. Notice that the program and the matrices were on file prior to these two executions, and that the total cost was 68¢ at overnight rates--this translates to \$1.70 at standard batch rates. If a run is attempted interactively, it would be wise to have at least a \$2.00 limit on the run.

```

1  PROGRAM ABELMATCHK
2  USED FOR CHECKING ABEL AREA MATRICES
3  1 REM PREPARED BY A. SCHUELINE UNDER THE DIRECTION OF:
4  2 REM PROF. JOHN P. WALTERS
5  3 REM DEPARTMENT OF CHEMISTRY
6  4 REM UNIVERSITY OF WISCONSIN
7  5 REM MADISON, WISCONSIN 53706
8  10 DIM A(50,50),B(50,50),C(50,50),D(5)
9  15 MAT A=ZER
10 20 MAT B=ZER
11 25 MAT C=ZER
12 30 PRINT 'WHAT IS THE NAME OF THE INPUT DATA FILE?'
13 35 INPUT X$
14 37 IF X$='0' OR X$='-2' THEN X$='ABEL.DATA.'
15 40 A$='.'
16 45 D=CNT(X$,A$)
17 50 IF D=0 THEN 60 ELSE 70
18 60 Z$='GUSE FILE.,'+X$+'. . '
19 65 GO TO 100
20 70 Z$='GUSE FILE.,'+X$+'. . '
21 100 EXEC Z$
22 105 OPEN FILE FOR SYMBOLIC INPUT,3
23 110 FOR I=1 TO 50
24 120 FOR J=1 TO 10
25 130 INPUT FROM 3:D(1),D(2),D(3),D(4),D(5)
26 140 K=S#J-4
27 145 K1=S#J
28 150 FOR K2=K TO K1
29 155 K3=K2-K+1
30 160 A(I,K2)=D(K3)
31 170 NEXT K2
32 180 NEXT J
33 190 NEXT I
34 210 FOR I=1 TO 50
35 220 FOR J=1 TO 10
36 230 INPUT FROM 3:D(1),D(2),D(3),D(4),D(5)
37 240 K=S#J-4
38 245 K1=S#J
39 250 FOR K2=K TO K1
40 255 K3=K2-K+1
41 260 B(I,K2)=D(K3)
42 270 NEXT K2
43 280 NEXT J
44 290 NEXT I
45 295 CLOSE3
46 300 MAT C=A*B
47 302 PRINT 'WHAT IS ALLOWABLE MATRIX ERROR?'
48 305 INPUT Q
49 307 IF Q=0 THEN Q=5.E-8
50 310 FOR I=1 TO 50
51 320 FOR J=1 TO 50
52 330 IF I=J AND ABS(C(I,J)-1)>=Q THEN GO TO 360
53 340 IF I<J AND ABS(C(I,J))>=Q THEN GO TO 360
54 350 GO TO 370
55 360 PRINT 'I='I,'J='J,'C(I,J)='C(I,J)
56 370 NEXT J
57 380 NEXT I

```

```
58 400 'IF NO ERROR PRINTOUTS HAVE BEEN PRINTED'  
59 410 'THE MATRICES ARE CORRECTLY ON FILE.'  
60 420 'OTHERWISE CHECK FOR PUNCH ERRORS'  
61 430 STOP  
62 99999END
```

BASIC CHEMISTRY-WALTERS.

BASIC R4-0-4 21125106 14 JUL 75

OLDIARLWATCHK

RUN

ARLWATCHK 21125107 14 JUL 75

WHAT IS THE NAME OF THE INPUT DATA FILE?

-2

WHAT IS ALLOWABLE MATRIX ERROR?

DEFAULT VALUE

-2

IF NO ERROR PRINTOUTS HAVE BEEN PRINTED

SHOWS MATRICES

THE MATRICES ARE CORRECTLY ON FILE.

OTHERWISE CHECK FOR PUNCH ERRORS

ARE CORRECT

TIME 1 10.174

RUN

ARLWATCHK 21125154 14 JUL 75

WHAT IS THE NAME OF THE INPUT DATA FILE?

-2

WHAT IS ALLOWABLE MATRIX ERROR?

ERROR BOUND

3.6E-8

I= 1

J= 2

C(1,1)=

3.0727505E-08

TOO SMALL

I= 1

J= 6

C(1,1)=

3.1799412E-08

I= 1

J= 7

C(1,1)=

-3.3816587E-08

I= 4

J= 6

C(1,1)=

3.3049299E-08

I= 5

J= 8

C(1,1)=

3.2241204E-08

I= 9

J= 10

C(1,1)=

3.1596449E-08

I= 9

J= 16

C(1,1)=

-3.0498104E-08

I= 15

J= 16

C(1,1)=

-3.5352012E-08

I= 16

J= 17

C(1,1)=

-3.3583434E-08

I= 21

J= 22

C(1,1)=

-3.0074449E-08

I= 22

J= 23

C(1,1)=

-5.1787021E-08

I= 32

J= 33

C(1,1)=

-4.7347236E-08

- WORST CASE

I= 34

J= 35

C(1,1)=

3.4996482E-08

I= 30

J= 41

C(1,1)=

-4.6579105E-08

ERROR ONE

I= 45

J= 46

C(1,1)=

-3.4968101E-08

TO ROUND OFF

I= 48

J= 50

C(1,1)=

4.0430567E-08

I= 49

J= 50

C(1,1)=

-4.5715537E-08

IF NO ERROR PRINTOUTS HAVE BEEN PRINTED

THE MATRICES ARE CORRECTLY ON FILE.

OTHERWISE CHECK FOR PUNCH ERRORS

TIME 1 8.391

BYE

UNIVAC BASIC 21126129 14 JUL 75

OFFIN

TOTAL COST BASED ON RATES FOR OVERNIGHT RUNS 50.48

IV. Introduction to ABEL3, the Abel Inversion Modeling Program

A. Phenomena to be modeled

In writing this program, the immediate goal was to have the ability to model various phenomena important in the observation of a plasma discharge. Such processes as emission (both line and background), absorption, intensity measurement noise, discharge wander, and instrument misalignment were of interest. In addition, provision was made for program expansion so that laboratory data collection could be carried out simultaneously with discharge modeling, and phenomena that have not yet been considered but which may be relevant may later be added. The principle calculational device used in this modeling is the Abel Inversion for converting radial (chemical) views of a discharge to lateral (observable) views and vice versa.

B. Gross program structure

ABEL3 is designed so that almost any combination of phenomena may be studied in a dynamically determined order. This requires that all subroutines be written as independently as possible and that the results of any computation be available as input to any other routine. Thus, the program is written as a "pinwheel" program with a number of operating subroutines linked together by a core routine which directs which subroutine is to be executed and what data is to be fed to that routine. Each

subroutine contains a number of options as to how the data is to be processed. Thus, the program acts as a giant pocket calculator, with the core routine providing the "function" buttons (analogous to the sine or arctangent keys on a calculator) and access to the data, and the subroutines actually processing the data. Because of this structure, each subroutine is viewed by the core director as simply a place to jump to within the program. Various procedures may be added to or deleted from the program without in general disturbing any other functions. In various sections to follow, the philosophy used in writing the subroutines will be discussed, instructions for the use of the program will be given, and modification procedures will be outlined. Be sure to read the section on rules for writing new subroutines before attempting to modify the program--there are only a few rules, but ignoring them could lead to incompatibilities between new routines and those already written, and conceivably to untimely program failure.

C. Philosophy of modeling

A three-dimensional discharge is physically a complicated phenomenon. Computer modeling of such a discharge is therefore also nontrivial. Further, it appears that some of the most useful information from a heterogeneous discharge can be obtained when some method of data analysis "does not work", indicating that new phenomena need to be taken into account.

The computer programs for modeling must therefore be written to encourage expansion and change, and also be structured to be as independent as possible of a particular discharge model. At the same time, the program's usage must be comprehensible to a variety of users. It is hoped that once the formal structure of the program is understood that it will be useable by those who have only minimal computer skills. This would be a difficult program for a total novice, however.

The essential skill in using the program is to be able to interchange quickly a chemical idea, the functional units (and their labels) of the computer program, and the command numbers representing the functional units and labels. An example not related to spectroscopy will be given.

There is an orchard and a vineyard. Call the orchard farm 1 and the vineyard farm 2. There are two types of nutrition (for present purposes): liquid (type 1) and solid (type 2). If it was specified that an individual had visited a farm and had grape juice, it would be evident that he had visited farm 2 and had nourishment of type 1. Three things have been interwoven in this paragraph:

- (1) An individual visited a farm, bought the liquid produced thereon, and in so doing obtained grape juice, which he drank (concept).

- (2) Description may be limited to succinct phrases; by stating "farm 2, type 1", and assuming that the item within quotes was consumed, the concept in (1) may be communicated (labeled functional units).

- (3) 2, 1 (command numbers).

Again the idea is the same, but stated in its most compact form.

Single digits are used to state a fairly complex thought. In summary the sequence was

English thought → terse labels → numbers .

By understanding all three, they may be used interchangeably to state the same thing.

In the modeling program, English thought is the mode presumed most comfortable for the user (any vernacular language will do, however). In English, the user formulates ideas to test. By looking over tables provided about the program, he then translates from English to terse labels to identify what is to be done and upon what data. In the tables, command numbers are given. The user inputs these numbers to the computer to control program operation. When the computer outputs information, it does so as command numbers, terse labels, or, often, both. It is expected that use of this documentation will familiarize the

user with the available labels for data and operations, and that when usage is attempted that the command numbers will be easily found.

There are six core questions which fall into four groups:

Which Subroutine?
Which Option?
Which Profile*?
Which Ring or Zone?

The first two groups inquire as to what operation is to be performed. The last two groups establish upon which data the operation is to be performed. In most instances there are no restrictions as to what operations may be performed, in what order, or upon what data. In fact, if the user chooses, he may alter the program so that new subroutines are added to, or replace, old ones; or he may change the labels on the data so that, for communications purposes, entirely different data is being manipulated. The disjointure between label and substance is the heart of the flexibility of the program.

Another way to view program operation is to think of the data as being on a turntable. As various subroutines are called, the data is brought to that subroutine, operated on in some way, and then returned to the turntable. Thus all data is resident in a

* Alternative wording: Where's the data that is to be worked on?

central location, and the user chooses which item is to be affected in what manner at what time. In this respect, the program is similar to full computer languages with data scratch pads such as MINITAB. An analogy might also be drawn to quantum mechanics, where subroutines would correspond to operators, and data would correspond to wave functions.

D. Loading and preparing programs for use

Preparing to model three-dimensional discharges is a somewhat lengthy but conceptually simple process. A punched deck of the Abel Area Matrices (producible using program AMXINV2 if not on hand), the program ABELMATCHK, and the program deck for ABEL3 must be available. Instructions for loading the matrices and checking them with ABELMATCHK have already been given. The matrices should be correctly loaded onto file ABEL*DATA before proceeding.

Program ABEL3 must be loaded via punched cards, and it is recommended that two separate runs be performed. The first run is used to load the core of the program, and the second is used to load the subroutines. Loading is expensive, because as many as 1500 cards may be input and that many lines listed.

There are two distinct program sections. One is the core of the program, listed on pages A-2-0-1 through A-2-0-11. This is a fully operable block of statements which consists of an initialization package, core operating routine for calling up the subroutines, and dummy subroutines to prevent undefined

operations. While it can perform no calculations relative to spatially resolved spectra, it is the hub onto which all calculational routines must be attached and may be useful in its own right for "playing" with the core commands for familiarization with core operation at low cost. The other section of the program is the package of functional subroutines, eight in number as of this writing. Any or all of them may be appropriate to a given problem, and may be loaded as desired.

There are two distinct types of punched cards. One type, called documentation cards, has a "C" in column 1, an asterisk (*) in columns 5 and 72, and useful information for program operation in columns 7-71. These should NEVER be loaded onto the computer, as they would give BASIC a bad and expensive case of digital indigestion. The other type of card is a program card, which contains information understandable to BASIC. The two types of cards are stored in alternating well labeled blocks in an order close to that in the program listing.

The remainder of the loading procedure described is designed to be as direct as possible for the user; there are less expensive ways to do the job but none simpler.

For the first run, three cards must be punched by the user. These are (1) a RUN card, (2) a PASS word card, and (3) a FIN card. The last of these is the simplest--starting in column 1 the card is punched

@FIN

The @FIN is the very last card in the deck. The password card is punched to employ the individual user's batch password. If no batch runs have previously been made by the user, this card will set the password. Suppose the password is "spark" (no more than six letters are allowed). Then the password card would read, starting in column 1,

@PASS SPARK

This may be placed anywhere in the deck, but is most easily kept track of if it is the second card in the deck.

The RUN card is also specific to an individual and project and is the first card in the deck. Presume the user's initials are AS, the project number is 2231 and his student or staff ID number is 1893602639. Then the RUN card, starting in column 1, should be:

@RUN/R AS,2231,1893602639,\$20.00,100

With the three cards prepared, get the three segments of the core routine card deck and stack them in order (noting where the segments end so the segments may be readily separated later).

Put the RUN and PASS cards at the front of the deck and the FIN card at the end. Load the deck via the service windows in the computer center. When the job has run, retrieve the three specially punched cards and return the core routine to the card drawer. To check that the program has loaded correctly, run the following batch run (or the interactive equivalent if desired):

```
@RUN                (etc.--use card previously punched)
@PASS SPARK
@BASIC CHEMISTRY*WALTERS.
OLD:ABEL3
RUN
STOP
BYE
@FIN
```

(all cards start in column 1)

In looking over the output from this run, after the "run" command is printed, a line should appear saying

BATCH OR TIMESHARE RUN; INPUT 'BATCH' OR 'TIME' OR JOB ABORTS

If this appears, all is correct and the rest of the program may be loaded. If it does not appear, the cause should be evident from somewhere in the two listings; get assistance if the problem is not readily evident.

Based on what operations are to be used, choose which subroutines are to be loaded (loading more than are necessary

adds both storage and execution costs). Take the three specially punched cards and sandwich between them the program cards of the selected subroutines. One plausible arrangement, dubbed "ABEL2" to distinguish it as a subset of ABEL3 will serve as an example. This version will not allow modeling of noise or smoothing effects but has all other preprogrammed capabilities. The order of the deck would be

```

@RUN          (as above)
@PASS SPARK
  subroutine 1 program cards (profile construction)
  subroutine 2 program cards (radial to lateral conversion)
  subroutine 4 program cards (shifting; reinitializing)
  subroutine 5 program cards (lateral to radial conversion)
  subroutine 6* program cards (output)
  subroutine 8 program cards (wander modeling)
@FIN

```

Again submit the deck at MACC; again perform the short test program and again if the question about BATCH vs. TIMESHARE prints out all is in order. Refile the program deck for the next user.

E. Operation strategy

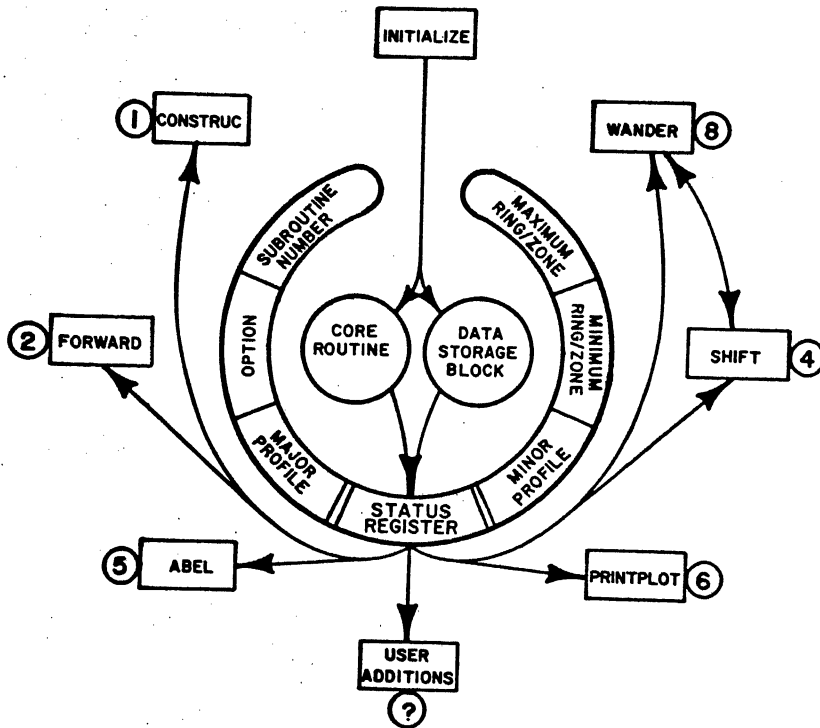
In this section it will not be of concern how to make program ABEL3 perform specific functions nor will usage syntax be considered. Rather the general program structure and

* Parts 6a, 6b, and 6c.

Figure A-2

Flowchart for One Version of the Abel Inversion
Program

PROGRAM ABEL2 "FLOWCHART"



SPARK WANDER MODELING
CONFIGURATION

operating sequence will be discussed. The approach used is that of a "pinwheel" program; that is, instead of executing the program in a fixed sequence of operations, the user chooses (with only minor restrictions) any arbitrary order of execution he desires. After each action has been specified, it is carried out and the program requests input as to the next step. The effect, as previously mentioned, is that of a pocket calculator. A flowchart for one version of the program has already been given. After one signs onto the computer and gets into BASIC, the commands

OLD:ABEL3
RUN

are entered and the initialization routine comes on line. After answering several questions related to initialization, the core control routine activates for the first time. The user is asked six questions which establish exactly what action the program is to take. The user tells the computer which subroutine and option within that subroutine to execute, what data profiles are involved (All data are stored in the "data storage block", and the profile numbers tell where within that block the desired data exist.), and which specific elements of the data profiles are to be affected (as the physical situation is modeled in terms of radial and lateral profiles, this specifies the radial rings and lateral zones of interest). With this information stowed in the status

On the other hand, some output may prompt a change in that sequence of operations; the ability to make such "on the fly" changes is one of the chief advantages of interactive computing.

An important feature of the "flowchart" is that there is a section marked "User Additions". ABEL3 need not be considered a "finished" program--any given user may wish to add options or routines. An entire section of this documentation is devoted to modification and addition techniques. As currently configured, ABEL3 would be awkward for on-line data collection. However, the addition of a brief subroutine would make on-line data collection a simple matter indeed (conceivably, one new option could be added to a subroutine already in existence). So the general strategy for effective use of ABEL3 is "plan ahead, but be light on your feet."

ABEL3 has certain assumptions concerning the physics of the discharge being modeled. The most important assumption is that the regions in which emission takes place and the regions in which absorption of light takes place are physically separated and that all absorption takes place in a cool region outside the hot, emitting core. The acronym devised for this model is DREAMS: Decoupled Region Emission Absorption Model of the Spark. This layered model is a constraint in using the program unless (until?) a nonsegregated model is programmed. In all matters involving noise generation, the noise is assumed to be white noise; this is

dictated by BASIC's random number generator function RND which produces only white noise. The coordinate system is such that one only looks at half of the discharge being modeled, the discharge is assumed to be cylindrically symmetrical, and only the right half of the discharge is viewed. This roughs out the approach taken in using ABEL3.

F. Types of terminals usable

ABEL3 was written to be explicitly usable from PEP 801 terminals and via batch processing. No explicit provision was made for running from a teletype (although with a few precautions this is possible). Directions will be given for activating the batch and PEP operating modes, and suggestions made for modifying the program for teletype compatibility. The easiest way to learn to use the program is at the PEP terminal; batch processing uses a more restricted control code and is not as forgiving of errors.

V. Detailed Program Capabilities

This section of the documentation goes through the individual subroutines and lists what capabilities each routine has. As each option is given, an example of how it might be used in spectroscopic modeling will also appear. The syntactical use of the routines is described in Section VII of this documentation. A sample run is given in Appendix A-5.

A. Core routines

Before modeling may be performed, certain core capabilities must exist in the program. These include: (1) program initialization, (2) general control of execution sequencing, (3) some means of inputting and doing arithmetic manipulation on the data to be used in modeling, and (4) output capabilities so that the results of the modeling are readily accessible. Upon starting the modeling programs, the initialization routine is entered, followed by the general control routine. The data entry and manipulation routine is Subroutine Construc (mnemonic for Profile Construction), and the output routine is Subroutine Print-Plot.

1. Initialization. Much of the program initialization such as clearing arrays, reading in the Area Matrices, etc. is transparent to the user. However, the user does specify several important parameters. First, the computer must be informed whether a run is being made as a batch run or as an interactive

run. The control statement inputs for batch runs are in a more compressed form than those for timeshare runs, and input prompts are not necessarily supplied in batch mode. If the run is set up as a batch run, the user is requested to input a job identification statement; this allows for labeling of a run as to its intent, date, or some other distinguishing characteristic.

The user then is asked to set up the noise generation facilities of the program in the desired configuration. This consists of two questions. First, one must decide whether the noise produced should be from BASIC's standard documentable noise sequence or from a nonreproducible (RANDOMIZED) noise sequence. The former method might be chosen if the propagation of noise through a series of calculations was to be monitored with the computer and checked by hand; the latter method might be appropriate if the user wished to insure that the noise pattern was truly distinct from all previous noise patterns he had used.

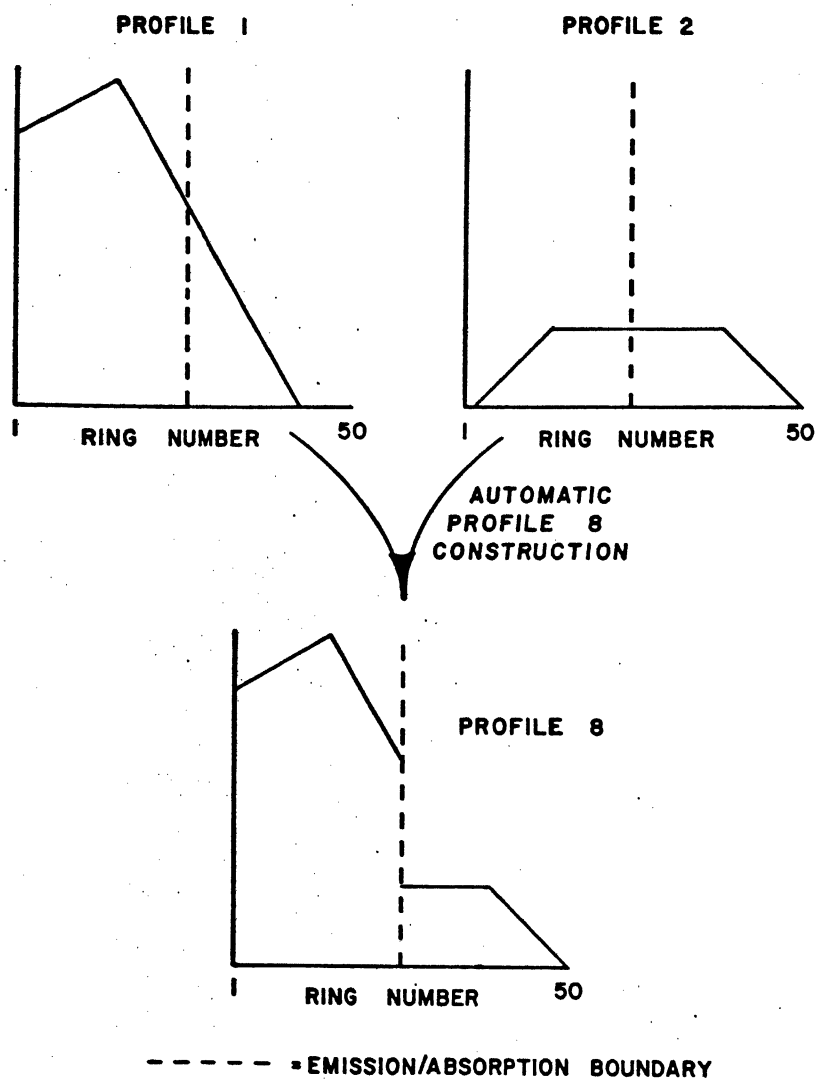
Next, the basic properties of the discharge to be modeled are entered; these are the zone or ring width in microns and the number of the last ring in which emission occurs (all higher numbered zones are assumed either to have no optical properties or to exclusively absorb light). Typical values might be a zone width of 50 microns and a "last emission ring" of 25 i.e. rings 1 to 25 emit light and rings 26 to 50 absorb light.

Finally, two flags are set. The first is the "transmittance profile protection" flag. It is normally turned on and prevents the user from attempting to do the Abel Inversion on absorption data unless the backlight intensity was set before the absorption data were calculated. If one were modeling spark wander, the user might want to turn the flag off; in general it should be left on. An aside is necessary before explaining the setting of the last flag: There are 19 different labeled profiles in the Abel modeling programs. The label on Profile 1 is "User Constructed Radial Emission Profile" and the label on Profile 2 is "User Constructed Radial Absorption Profile". Often, one desires to use data from Profile 1 for those rings which emit and use data from Profile 2 for those rings which absorb in a given subroutine. As a convenience, Profile 8 may be automatically generated as the "User Constructed Emission/Absorption Profile". The drawing on the next page illustrates the procedure. End of Aside. The last flag set determines whether Profile 8 will be automatically generated. This generation only occurs when Profiles 1 or 2 are manipulated within Subroutine Construc. It has been the author's experience that automatic generation of Profile 8 is very handy.

2. General control routine. There are six items to be specified in the core control routine. These are (1) which subroutine is to be called; (2) which option within that

Figure A-3

Meaning of "Automatic Profile 8 Construction"



subroutine is to be executed; (3) which of the 19 possible profiles is to be the "major profile" affected by the subroutine; (4) which of the profiles will be the "minor profile" affected (exact meanings of major and minor vary with the routine and option--as each option is listed below, the specific uses of the major and minor profiles will be clarified); (5) which zone or ring (1 through 50) will be the lowest numbered ring or zone affected by the routine being called; and (6) which zone or ring (again 1 through 50) will be the highest numbered ring or zone affected by the routine being called. The first two items specify what operation is to be performed; the last four items are used to direct which specific data items are to be so affected.

While it is possible for the user to enter unique commands each time he specifies the action the program is to take, default control values are also provided (except in the case of choosing a subroutine, for which there is no default). Further, a procedure is provided for changing the default values if the user so chooses.

The core routine has several alphabetic commands in addition to the standard numeric ones. The only one which need be mentioned here is the command which terminates program execution in a manner compatible with the plot routine. In response to one of the core questions, either a letter S or a letter T is entered.

Entering the word STOP to halt execution will lead to loss of all plot data in most situations, and is to be avoided.

The use of the control routine can most easily be understood by giving examples of subroutines and showing what control values might be entered to use these routines.

3. Subroutine Print-Plot. This subroutine can perform the following operations, either singly or in any combination:

- (a) print out the data input in the major profile along with the base ten logarithm of that data (the value -12345. being printed for each input data point that equals zero);
- (b) plot the input data instantaneously in rough form using a modified version of MINI-PLOT, D. T. Stueland's BASIC plotting program; or
- (c) plot the input data using D. T. Stueland's PEPSUB (all PEPSUB drawn plots appear at the end of the program run).

Print-Plot is subroutine number 6, and the major profile specified is the profile containing the data to be output. Any profile may be specified for the minor profile; it is totally ignored in this routine. Output consists of those elements of the major profile falling between and including the lower and upper zone/ring limits specified in the control routine calling sequence.

A complete listing of the options for Print-Plot appears on the next page:

Option Number	Function
1	Plot using MINIPLLOT
2	Plot using PEPSUB
3	Plot, first with MINIPLLOT, the with PEPSUB
10	Print out data
11	Print out data, then plot using MINIPLLOT
12	Print out data, then plot using PEPSUB
13	Print out data, then plot using MINIPLLOT, then plot using PEPSUB

The pattern that is evident in the option numbers above is not accidental. Note that there are essentially three options: option 1 plots using MINIPLLOT, option 2 plots using PEPSUB, and option 10 prints out data. By adding various option numbers together, one can get various combinations of options; option 13 can be thought of as option 10 plus option 3. This type of option combination is used in various other subroutines and should be useful as a mnemonic for recalling the meaning of options.

The user exercises little direct control over the drawing of plots; all of PEPSUB's and MINIPLLOT's options including axis labeling, title assignment, and plot symbol and dash code assignment have been "hardwired". From the major profile number, the program looks in a table of alphanumeric variables for the

correct labels, title, etc. This table may be changed as described in Section VIII. While the complete hardwiring removes some plotting flexibility, it speeds and eases program utilization.

There are several questions which the plotting routines request the user to answer, however. If one is plotting both emission region data and absorption region data, the routine asks if the user wants to plot both types of data with the same scale on the vertical axis (in general the answer is no--absorption values may run from 0.00 to 2.0 or 3.0, while intensity values may run in the thousands). Additionally, the user may specify if a different symbol should be used for plotting the data corresponding to the absorption region than should be used for plotting the emission region data. In all cases when MINIPLOT is entered and/or when PEPSUB is entered, the user is requested to supply a "plot status". The most useful answers are NEW, OVERLAY, and ABORT. A NEW plot sets up a new set of axes, titles, labels, etc. and plots the input data. An OVERLAY plot plots the input data on top of the previous plot. MINIPLOT and PEPSUB run independently, so that one may use either status of plot in either routine within the same call to Subroutine Print-Plot. ABORT prevents plotting and sends the user directly back to the core control routine. Other less frequently used responses are discussed in Section VI. PEPSUB produced plots

are obtained by properly terminating the program from the core control routine (entering T or S in response to any of the core questions instead of a number--this too is discussed in Section VII).

As with all the subroutines, an appendix is provided summarizing the capabilities of Subroutine Print-Plot. As noted there, the default option is option 11 and the default major profile (i.e. the default profile to be output) is profile 6, the computed emission/absorption profile. The minor profile is immaterial in this case, and the default ring/zone values are as given for all the subroutines (see Section VII for details).

4. Subroutine Construc. Being capable of outputting profiles is of little benefit if there is no information in the computer which needs to be output. The subroutine which allows one to enter data into the Abel modeling program is Subroutine Construc. Construc allows one to perform 15 different mechanical manipulations on the numbers contained in any numbered profile (or profiles as the case may be). These operations may be grouped as follows: (a) to whatever contents are in a given profile when Construc is called, add some additional numerical values corresponding to various conceivable line shape profiles. Such profiles might be Gaussian (either on or off axis), homogeneous (same value added to the contents of each element of

the profile), or ellipsoidal (added values fall off from a maximum on axis to zero in some user chosen ring or zone).

(b) Modify in toto or in part the contents of the chosen profile by inputting directly from the computer terminal values to be inserted in various rings or zones of the profile, scale factors to be applied to various locations, or additional numerical amounts to be added to the contents of the profile. (c) Combine the major and minor profiles in various ways, either adding them together, subtracting one from the other, or cross-multiplying them (as in a convolution). (d) In addition to any other option specified, set the contents of the major profile to zero prior to executing the other specified operations.

A list will now be given of each of the options. Following this list, some description and illustration will be given of the effect of choosing various options; it is recommended that the beginning user "play" with Construc in combination with Print-Plot and the control routine until he is comfortable with these routines prior to using the other routines in the program. Horizontal lines indicate groups of options which may conceptually be grouped together.

"Canned" profile construction

- 1 To whatever is in the major profile, add on on-axis Gaussian profile with amplitude and half-width at half-height as determined by the user.

- 2 Same as option 1, except that the Gaussian is an off-axis Gaussian centered in whatever ring or zone the user chooses.
 - 3 Same as option 1, except that an ellipsoidal profile falling to zero in the zone or ring the user chooses is substituted for the Gaussian profile.
 - 4 Same as option 1, except that a homogeneous profile is constructed.
-

User Direct Input Profile Construction

- | | |
|--|--|
| <ol style="list-style-type: none">5 Input directly the values desired for specified rings or zones within the bounds allowed by the ring max. and min. as given in the control routine.7 Input a scale factor to be applied to individually selected rings or zones within the bounds set in the control routine. | <ol style="list-style-type: none">6 Input directly the values desired sequentially for all rings or zones within the bounds allowed by the ring max. and min. as given in the control routine.8 Sequentially enter scale factors to be applied to each zone or ring within the bounds set in the control routine. |
|--|--|

- | | |
|--|---|
| <p>9 Input a number to be added to the value already present in a specified ring or zone.</p> | <p>10 For each zone or ring within the bounds set in the control routine, input a number to be added to whatever is already present in the profile.</p> |
|--|---|

Note: For options 1 through 10, only the major profile is affected, so far as user control is concerned. In addition, profile 5 is "hard-wired" as an internal scratch register.

Additional Profile Manipulation

- 11 Add, in a zone-for-zone or ring-for-ring fashion, the contents of the minor profile to the contents of the major profile. The resultant is stored in the major profile; the minor profile is unaffected.
- 12 Subtract, in a zone-for-zone or ring-for-ring fashion, the contents of the minor profile from the contents of the major profile. The resultant is stored in the major profile and again there is no net effect on the minor profile.
- 13 Input a single scale factor to be used on each element of the major profile. This is equivalent to option 8 except that one scale factor is applied to all rings or zones instead of having to enter one scale factor for each zone

(option 8 should be used if different scale factors are desired for different rings or zones).

- 14 Convolute the major profile with the minor profile and store the result in the major profile. The minor profile is unaffected. The convolution consists of multiplying the first element of the major profile by the first element of the minor profile, the second element by the second element, and so on.
- 15-19 Options not used; if attempted, these options will generate a diagnostic and return the user to the control routine.
- 20 Clear the major profile, i.e. set each element (within the bounds set by the control routine ring or zone minimum and maximum) equal to zero.
- 21-34 Identical to 1 through 14, except that the major profile is cleared prior to execution of the option. For example, option 21 is option 20 (clear profile) followed by option 1 (add an on-axis Gaussian to the data already resident in the major profile).

Some illustrations are in order. Let us assume that in some way (prior calls to Construc actually), profile 1 contains a homogeneous profile in rings 10 through 40 inclusive and that profile 2 contains an off-axis Gaussian of half-width ten rings centered in ring 25. Diagrams on ensuing pages are designed to show:

Figure A-4**Examples of Options in Subroutine Construc**

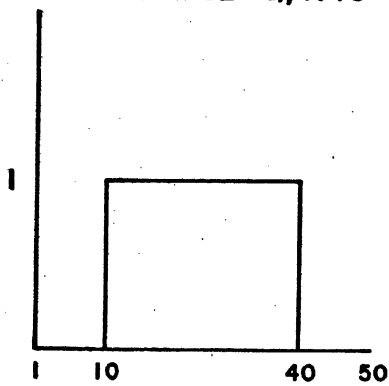
(Page numbers in heading are from a draft copy of this documentation and should be ignored. All examples are discussed in the text.)

EXAMPLES USING SUBROUTINE CONSTRUC

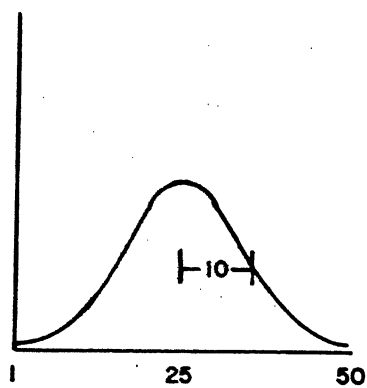
I INITIAL CONDITION II EXAMPLE a), P.48

III EXAMPLE b), P.48 IV EXAMPLE c), P.48

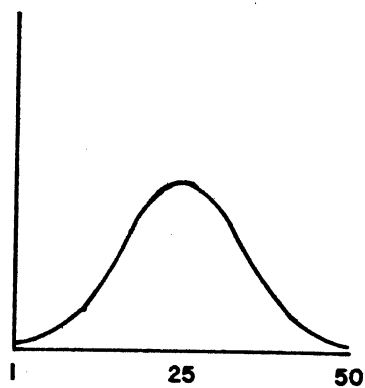
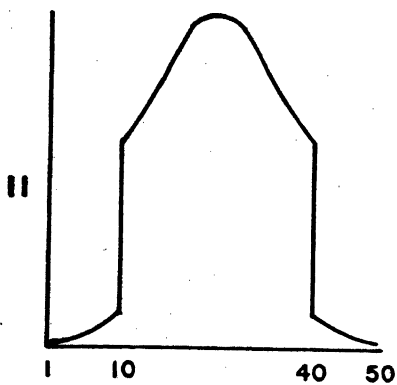
V EXAMPLE d), P.48

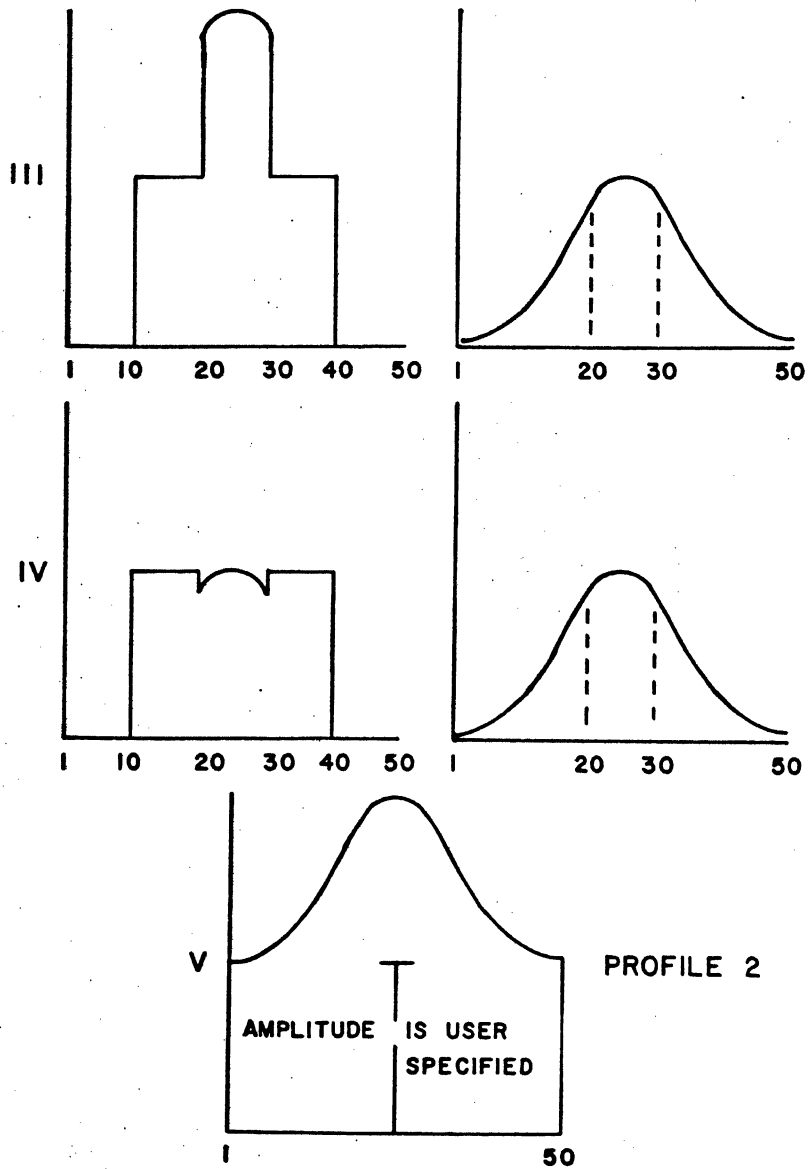


PROFILE 1



PROFILE 2





- (a) The effect of executing option 11 on all rings 1 through 50 with profile 1 the major profile and profile 2 the minor profile.
- (b) The effect of executing option 11 only on rings 20 through 30 with the same major and minor profiles.
- (c) The effect of executing option 31 on rings 20 through 30.
- (d) The effect of executing option 4 on profile 2, all rings 1 to 50.

Construc is subroutine number 1; default major profile is 1, the user constructed Radial Emission Profile, and the default minor profile is number 11, the user constructed Background Species distribution. Default option is 4, homogeneous profile construction.

B. Radial/lateral profile conversion routines

Two subroutines are employed in the program for calculations which convert between radial and lateral profiles. Classically, conversion from a lateral profile to a radial profile is called the Abel Inversion, and so the lateral to radial conversion subroutine has been christened Abel. The radial to lateral conversion routine, used to take user constructed species distributions into theoretically observable lateral profiles, is subroutine Forward. In both routines, data is processed only for the zones and rings specified; it is thus possible (at times intentionally) to calculate profiles while ignoring relevant data.

One may often find that matching physical and calculational conditions poses subtle difficulties in these routines particularly.

1. Subroutine Forward. There are six options in this subroutine, two of which are simply overrides on the emission/absorption boundary set during initialization. There are three profiles which behave in special ways in this subroutine:

- (3) Except for option 4, output is always to profile 3.
In option 4, output is placed in the input major profile.
- (4) In options 1 and 3, profile 4 is hardwired as the backlighting source's intensity profile (for absorption modeling). If the user has not constructed a backlight profile prior to calling Forward, a homogeneous backlight profile of intensity 100 in each zone is generated and a diagnostic printed.
- (8) In option 1, if profile 8 is the major profile (radial emission profile), it is automatically taken as the minor profile as well (radial absorption profile), overriding the specification of the minor profile in the control routine.

The options themselves are as follows:

- (1) Convert the input radial emission (major) and radial absorption (minor) profiles into a lateral intensity profile. Note that only those rings and zones specified in the control routine will have any effect on the output (or be affected)--thus if the last emission ring is 25 and there is absorption in ring 40, but the last ring accounted for in the calculations is 35, only emission calculations will be performed.
- (2) Assuming a pure emission model of the discharge, convert the major profile from a radial profile into a lateral profile (input data is unaffected; output is to profile 3). The emission/absorption boundary is observed, so that absorption region data is ignored.
- (3) Assuming a pure absorption model of the discharge, calculate a radial profile from the input lateral profile. Again, the emission/absorption boundary is enforced so that only zones and rings outside the emission region can be affected.
- (4) The major profile is taken as a lateral intensity profile for both input and output; and the minor profile is taken as a radial absorption profile. The major profile is convoluted with the absorption distribution in the minor profile, with the convoluted

result replacing the input major profile. There is no effect on the absorption region of the major profile.

This option might be used if a fixed radial absorption profile were to be convoluted with various lateral intensity profiles for modeling purposes.

- (12) Same as option 2, except that the emission/absorption boundary is ignored. Thus even if the boundary is in ring 25, an emission profile extending to zone 50 could be modeled. Use of this option would normally prevent later use of absorption modeling, although there are no internal safety flags to prevent such mixing.

- (13) Same as option 3, except that the emission/absorption boundary is ignored. Absorption profiles extending within what is nominally the emission region may thus be modeled. Note however that this does not allow modeling of emission and absorption in the same region of space--it simply discards the emission/absorption boundary (for the duration of the option execution only) and discards the emission part of the model.

Forward is subroutine number 2. Default major profile is 8 and default minor profile is 2. The default option is 1.

2. Subroutine Abel. The options in this subroutine are the inverse of option 1 through 4 in subroutine Forward. Again there are several profiles which behave in special ways in this subroutine:

- (4) Behaves in the same way that it did in subroutine Forward.
- (6) Hard-wired output profile unless option 2 is used. For option 2, one has the choice of outputting to profile 6 or profile 7. The label on profile 6 is "Computed emission/absorption profile"; on profile 7 the label reads "Absorption uncompensated calculated emission profile". Aside from label differences, the use of a second possible output profile may provide some additional usage flexibility.
- (7) See (6) above.
- (15) This is essentially a scratch register, but a very handy one; in the process of peeling absorption information away from emission information, the lateral intensity profile, compensated for absorption effects, is calculated and placed in profile 15. While this is regarded as simply an intermediate result by the subroutine, the user may realize some utility in its existence.

The emission/absorption boundary is employed only in options 1 and 4 in subroutine Abel; the function which would be served by

invoking that boundary in a modification of options 2 or 3 is served by specifying the operating rings and zones in the control routine. The options are:

- (1) Perform a full Abel Inversion on the input profiles, assuming emission is occurring in the interior of the discharge and that absorption is occurring in the surrounding region. The major profile must contain the lateral intensity data for both the emission and absorption regions of the discharge (the profile in the absorption region corresponds to transmittance based on the backlight profile). The minor profile is taken as the backlight profile (note that this may be different than profile 4, in contrast to subroutine Forward where the backlight profile is hard-wired as profile 4).
- (2) Invert the major profile assuming emission to be the only process occurring in the discharge. The major profile is taken as the lateral intensity profile; the minor profile is not used.
- (3) Invert the major profile assuming absorption to be the only process occurring in the discharge; here the minor profile is used as the backlight profile.
- (4) Take the lateral intensity profile in the major profile, and assume that the light so observed has passed through an absorber whose radial profile is given by the minor

profile. Calculate the radial emission profile corresponding to these data. The backlight profile number is internally set to 4, but this need not be of concern as no external affect results.

Default values in this routine are as follows: major profile: 3, minor profile: 4 (it is suggested that this be used except for option 4 on a routine basis). Default option is 1, and Abel is subroutine number 5.

C. Physical effects modeling

Besides emission and absorption, routines have been written to model the effects of noise, data smoothing, spark wander, and lateral optical misalignment. The names of these routines are, respectively, Noise, Smooth, Wander, and Shift. To use subroutine Wander, subroutine Shift must be part of the compile program (this was shown in the program flowchart previously). The pattern of subroutine structure evident above is continued in these routines. In particular, the "trick" of adding ten to a previous option to get a slightly modified option number (see previous cases in subroutines Construc, Print-Plot, and Forward) is used in several places.

1. Subroutine Noise. Observed lateral profiles may be subject to noise from a number of sources, each of which produces random data variations related in different ways to the

input data. Subroutine Noise can add noise to input profiles in various ways, and in addition stores the noiseless (input) profile for later reference. Available options are:

- 1 Add noise independent of the data being operated on. The user types in the peak-to-peak noise amplitude which is to be added to the noiseless data.
- 2 Add noise whose amplitude is proportional to the maximum value of data in the emission region of the input data profile. The user specifies the proportionality constant in terms of the signal to noise ratio at that maximum value point.
- 3 Same as option 2, but the maximum value of the data in the absorption region of the input data profile is used in place of the point in the emission region.
- 4 Add noise proportional to each data point's value.
- 14 Add noise proportional to the square root of each data point's value.
- 24 Add noise proportional to whatever power of the input data points the user chooses.

The major profile contains the noiseless data upon entry into the subroutine; after the subroutine has completed its work, the major profile contains the now noisy data and the minor profile contains the noise free data that was in the major

profile when the subroutine was called. Noise is subroutine number 3, default major profile is 3, default minor profile is 9, and the default option is 2.

2. Subroutine Smooth. The inverse of adding noise to a profile is smoothing the data to attempt to alleviate the noise problems. Subroutine Smooth allows the user to smooth the data with a "triangular smoothing function" or a three point smooth. Only two options are provided: Using option 1, the data is not smoothed across the emission/absorption boundary, whereas with option 2 the smoothing routine ignores the boundary. In option 1, essentially 2 smooths are conducted; one smooths only the emission data, and the other only the absorption data. Smooth is subroutine 7, and the default option is 1. As with the noise routine, the unsmoothed data is preserved in the minor profile before the major profile is smoothed. The default major profile is 3, and the default minor profile is 12.

3. Subroutine Wander. As its name implies, Subroutine Wander models the effects of spark wander in a plane perpendicular to the observation system optical axis. It is essentially a "front end" routine for Subroutine Shift. The major profile (default is 3) is used both to input the data which is to be subjected to wander and for output of the final result. The minor profile (default is 16) is used for transmitting the input

data to Subroutine Shift. Profile 13 is hard-wired into Subroutine Shift and at the end of execution of the subroutine contains the originally input (major profile) information. Profile 17 is an accumulator used to "integrate" the results from each discharge which has "wandered".

Two options are provided (default option is 1):

- 1 Sparks wander in a random fashion, plus or minus at most the number of zones chosen by the user.
- 2 Spark wander falls within a manifold which peaks on axis and falls off as $k \cdot (1/x^2)$ on either side of the axis so that no sparks fall more than a specified distance from the axis.

When option 1 is chosen, the random number generator in BASIC puts down as many sparks as the user chooses, each spark being centered in a random zone within plus or minus the user chosen amount with respect to the spark axis. In option 2, a preprogrammed symmetrical distribution of the sparks across the axis is put down, with most sparks falling near the axis. Note that wander is always in a plane perpendicular to the experiment reference line, so that depth of field problems are not considered. Further, the random number generator produces white noise. It is not known whether the model for wander used in this routine bears any relationship to actual lab results.

Wander is subroutine 8. Subroutine Shift must be available for call by Wander for any operation.

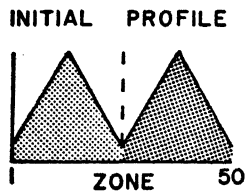
4. Subroutine Shift. Subroutine Shift, number 4, contains two distinct sets of options: Those which shift data back and forth within a given profile, and those which allow the user to reinitialize portions of the program. The latter will be discussed first as they merely provide a conduit to routines previously used.

Option 5 allows almost total reinitialization of the program. All numerical arrays and flags are cleared, zone width, flag values, and number of emission zones are all reset, and essentially the program starts fresh. Not affected are: plot output status (no previously made plots are lost), batch versus timeshare status, default option and profile numbers, or randomization of random numbers. In option 6, only the outermost emission ring number is reset, without affecting data already computed. Use option 6 with caution!

The other options, 1 through 3, 11 through 13, and 4 (grouped by their properties rather than numerically, as will be evident shortly), are used to move the data in a profile either left or right with respect to the optical/discharge axis in a variety of ways. A figure is attached to aid understanding these various modes. The option numbers (except 4, described later) and diagrams should be surveyed at this point for familiarization. The options have been numbered in a way that hopefully displays a recognizable set of patterns. The patterns are as follows:

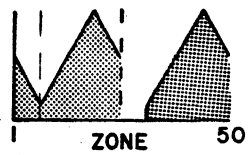
Figure A-5

Shift Routine Options

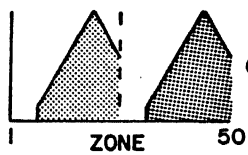


SHIFTED PROFILES

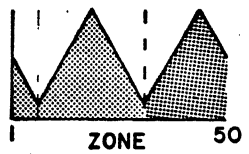
OPTION I



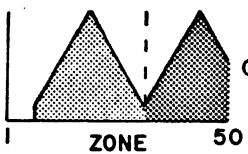
OPTION II



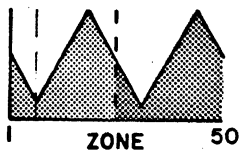
OPTION 2



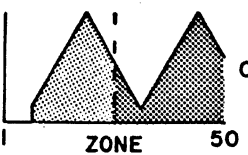
OPTION 12



OPTION 3



OPTION 13



- - - -

EMISSION/ABSORPTION BOUNDARY

- - - -

CENTRAL REFLECTION AXIS

If a single digit option is used, sections of the profile that have been cleared as a result of the shift are refilled, if necessary by reflecting data across the central axis of symmetry (discharge axis or optical axis). This would be appropriate behavior for a lateral profile, as a shift to the right brings some portions of the discharge, previously to the left of the optical axis, into view. A double digit option does not allow reflection or filling. One example of an application for these options would be the expansion of a radial atom profile from the central discharge axis. Outward migration of the atoms would be equivalent to rightward movement of the radial profile. Reflection would be inappropriate as the axis does not move; only the atoms move with respect to that axis. In any given situation, the appropriateness of filling or nonfilling must be determined "on the fly". A first approximation might be that lateral profiles be operated on with single digit options, and radial profiles be operated on with double digit options, but this should not be regarded as absolute.

The option numbers 1 through 3 vary the way in which the emission/absorption boundary is considered in the profile shift. In options 1 and 11, the boundary is "enforced", that is, no data is permitted to shift across the boundary, and the boundary remains in its present position. In options 2 and 12, the emission/absorption boundary is shifted along with the data.

Note that this will affect calculations on profiles other than the one undergoing the shift. Finally, in options 3 and 13, the emission/absorption boundary is ignored during the shift, but is still available for calculations elsewhere in the program. Again, careful consideration of the physical situation is necessary when choosing among these options. It has been the author's experience that options 2 and 3 are of most common utility. This may be regarded as a starting point, but in no way constitutes an absolute instruction.

The figure showed profiles which were shifted +10 zones, i.e. 10 zones to the right. A left shift is indicated as a negative shift, for example, -10 zones. In negative shifts, the zones emptied by the shift are filled with zeroes in most cases. If profile 3 is shifted and the outer zones lie in an absorption region, the data in the vacated zones are set to 100, i.e. 100% transmission of the backlight profile.

The remaining description of Shift's operation gets somewhat intertwined; to facilitate understanding, the remaining topics will be listed. If as each of them is discussed some points seem unclear, try reading through the remainder of the discussion and then returning to the troublesome point; hopefully additional information will have cleared up the problem by then. The topics are: uses of profiles, default values, saving unshifted profiles, special handling if major profile=3, and option 4.

In all cases, the major profile is shifted as defined by the option number and shift amount. The minor profile, generally assumed to be the background intensity profile, is unaffected unless the major profile is profile 3. Scratch registers used for saving unshifted profiles are 13 and 14; 13 is the only profile so used unless the major profile is 3.

Default option number is 4, default major profile is 3, and default minor profile is 10.

So that errors may be corrected or the preshift data may be accessed for any reason, all data is stored in a storage register (generally profile 13) prior to being shifted. This data is accessible via any routine in the program, but is overwritten each time an option 1 through 3 or 11 through 13 in Subroutine Shift is executed. Thus, while the data are saved before shifting, this saving is volatile, and the user may wish to move the saved data to other scratch registers for longer term storage.

If the major profile is profile 3, the lateral intensity profile, it is assumed that the background intensity profile shifts also, and that a left (negative) shift will expose some of the backlight profile directly to the observer. Thus setting major profile=3 invokes shifting of the minor (background) profile, with the major profile saved in its unshifted form in profile 13 and the unshifted minor profile saved in profile 14. If a left

shift occurs, the backlight profile, profile 4, has its outer zones (the number of such zones being the same as the magnitude of the shift) filled with data values 100 so that both absorption data in profile 3 and the backlight show 100% transmission to be taking place in the outer zones. The unshifted backlight profile is not saved. When shifting profiles containing absorption data, it is recommended that a homogeneous backlight profile with all data = 100 be used so that the shifting process does not introduce insidious unanticipated arithmetical errors.

The last option in Subroutine Shift, option 4, is used to "unshift" previously shifted profiles. It actually does two things: (1) take whatever data is in the scratch registers for saving unshifted data and return these numbers to the major profile (major and minor if the major profile is profile 3) and (2) restore the emission/absorption boundary to its value just prior to the most recent shift. Notice that the backlight profile is unaffected by the unshifting, and no actual shift computations take place--the contents of one set of registers are simply transferred to another set. The resetting of the emission/absorption boundary works regardless of which option 1 through 3, 11 through 13 was used in performing the previous shift, but the "depth" of the restoration is only one shift operation. For example, if option 2 were executed twice, first

with a shift of +2 and then with a shift of +3, and then option 4 were executed, the emission/absorption boundary would end up shifted +2 from its initial position.

D. Program structure and core constraints

When all eight of the present routines are loaded, there is very little extra core space in the Univac 1110 computer. To remove an unneeded routine to allow insertion of another routine or simply to save on execution costs, an appropriate regimen should be followed. This will be outlined shortly. Further, if new routines are to fit with present software, they should be designed to follow the form laid down for the present routines.

A table is given below stating the names of the various routines and the statement number corresponding thereto. NEVER Edit Resequence this program! Line numbers are used not only because BASIC requires them but also to ease manipulation and insertion of subroutines by users.

Routine	Number	Line Numbers
Pinwheel Core; Initialization	None	1-3500
Construc	1	4000-5000
Forward	2	6000-7000
Noise	3	12000-13000

Shift	4	14000-15000
Abel	5	16000-17000
Print-Plot	6	8000-8900
Modified Pepsub		9000-9999
Modified Miniplot		10000-10999
Smooth	7	18000-19000
Wander	8	24000-25000
Termination	None	11000-11500
Service Slave Routines	None	15900-15999; 22000-22100
End	None	99999
Available for general use		23000-24000; 26000-99998

To delete a given subroutine, determine what line numbers it comprises (for example, subroutine Abel, in lines 16000-17000 could be deleted). Deletion requires two steps:

- (1) Deletion of the lines containing the subroutine, and
- (2) Insertion of a dummy subroutine so that the program will still operate.

Step (1) is accomplished by calling up the program from the disk with the file write enabled:

```
@BASIC CHEMISTRY*WALTERS//01.  
OLD:ABEL3
```

and then DELETEing the appropriate lines:

```
EDIT DELETE 16000,17000
```

Step (2) is accomplished using page 0-11 of the program listing.

Simply type in all lines numbered in the same block of statements as those which the deleted routine used to occupy.

Example:

```
16010 Print 'Subroutine Abel Absent. Load if desired.'  
16035 Return
```

Again be sure to use the line number shown or unexpected program operation may result.

Details of how to construct new routines, relabel a profile, etc. are given in a separate section. Essentially the rules say that a subroutine may operate in any manner at all provided parameters are passed from the core routine in a standard manner and the data is processed in a flow through (as opposed to dead end) fashion.

VI. Principles of Subroutine Operation

The operation of subroutines Forward, Shift, Wander, and Abel is described in an article in the open literature (A. Scheeline and J. P. Walters, Anal. Chim. Acta, Section on Computation and Optimization Techniques, 1 (1), (1977)) and in the body of this thesis. The other four subroutines will be explained briefly here.

A. Subroutine Construc

This routine provides a means for taking profiles and adding, subtracting, scaling, or cross-multiplying them. Also, the information to be inserted may take one of several functional forms in addition to external input. The various options will be described in the same groupings as those used V.A.4 above.

All profiles are contained as rows in a two-dimensional array, dimensioned

V(25,50)

(The present program only allows use of the first 19 rows.) Thus the first index gives the profile number (with labels as listed at the top of page 0-2) and the second index gives the ring or zone number with 1 being closest to the optical axis or discharge center and 50 being farthest away from the axis. If in calling

a given subroutine, profile 3 is specified, then the array elements which may be affected (subject to possible constraints from other sections of the core setup or called routine) are

$$V(3,J), J=1,50$$

1. Canned profile construction. For the four "canned" profiles, the profile information is some function of ring or zone number:

$$P(J) = f(J)$$

For a homogeneous profile, this is just a constant:

$$P(J) = K$$

whereas for an off-axis Gaussian, it is a complicated function of ring/zone index:

$$P(J) = K_1 \exp(-K_2(J-J_0)^2)$$

where J_0 is the ring or zone in which the Gaussian is centered.

Code for profile construction appears on pages 1-1 and 1-2, lines 4105-4225. In general, if K3 is the profile number and

$f(J)$ is the function giving profile shape, options 1-4 perform the following:

$$V(K3,J) = V(K3,J) + f(J)$$

for all J allowed by the ring/zone limits set in the last two questions of the core routine. Note that profile functions $f(J)$ are added, not inserted into the profile--option 20 is needed to clear out old information when "stacking" of profiles is not desired.

2. User direct input profile construction. Options 5-10 inclusive allow three operations in two separate modes. The operations using notation developed above, are:

5 and 6: $V(K3,J) = [\text{user input number}]$

7 and 8: $V(K3,J) = [\text{user input number}] * V(K3,J)$

9 and 10: $V(K3,J) = [\text{user input number}] + V(K3,J)$

The differences in the two modes of operation (odd numbered options and even numbered options being the two modes) lies in which zones or rings are affected, and in what order. For present purposes, assume any ring 1 through 50 may ab initio be processed by subroutine Construc (more restrictive processing may be specified by the core routine). If an even numbered option is

specified, user input concerning every zone 1 through 50 will be solicited. Once the option is started, input must be provided for all 50 queries. If an odd numbered option is specified, the user supplies both the ring/zone number to be affected and the necessary data for that zone. Thus only a handful of zones, in arbitrary order, may be adjusted in value. When no more input is appropriate, the user specifies impossible input (say zone 55, which is outside the program's range) and the core routine is recalled.

3. Other options. Options 11, 12, and 14 allow combination of the major and minor profiles. If the major profile is profile K3 and the minor profile is profile K4, then (using notation similar to that above) option 11 is

$$V(K3,J) = V(K3,J) + V(K4,J) \text{ for all } J ,$$

option 12 is

$$V(K3,J) = V(K3,J) - V(K4,J) ,$$

and option 14 is

$$V(K3,J) = V(K3,J)*V(K4,J) .$$

There is no option for dividing the major profile by the minor profile; such an option did not occur to the author until this documentation was being written. Perhaps this could be added as option 15 at some future date.

Option 13 allows scaling of an entirely profile by some constant. This is similar to options 7 and 8, except that one entry scales every ring or zone allowed by the control routine instead of requiring separate input for each ring or zone. That is, if the input scale factor is 5, then

$$V(K3,J) = 5*V(K3,J) .$$

Option 20, either alone or in combination with any other option, clears the major profile:

$$V(K3,J) = 0 .$$

Thus to insert an off-axis Gaussian (option 2) into a profile already containing other data, the option chosen would be 22--erase the old data, then add in an off-axis Gaussian.

B. Subroutine Print-Plot

This subroutine consists of four major units:

- (1) Printout routine
- (2) Plot setup routine

- (3) Miniplot (modified from program written by Dr. D. T. Stueland)
- (4) Pepsb (modified from the original version written by Dr. D. T. Stueland).

For ordinary use, the discussion of this subroutine in Section V was sufficient; units (1), (3), and (4) are reasonable straightforward. To preserve input data flexibility while minimizing required user input, section (2) is fairly involved. In fact, future modification of section (2) could conceivably present difficult coding problems.

The printout routine simply takes the input data as defined by the profile number and ring/zone limits, applies the appropriate labels, and prints out the ring/zone number, data value, and base ten logarithm for each datum. To prevent attempts to take the log of 0, a check for the datum "0" may override the log printout and substitute the number "-12345", in the log column of the output. The whole print routine takes only 18 lines of code (page 6-1, lines 27-44).

MINIPILOT is a version of Dean Stueland's all BASIC ASCII character plot routine with all options, save for specifying NEW or OVERLAY plots, hardwired, and out of the user's control. Plot symbols, labels, and data scaling are all provided by the plot setup routine. Similarly, PEPSUB is hardwired. The January 1975 version of PEPSUB was used as the basis for this routine.

PLOT STATUS commands available but infrequently used in
PEPSUB are:

LAST
DONE
CLOSE

If LAST is given as the "Plot Status", the data in the major profile is plotted, after which no more data may be plotted using PEPSUB. CLOSE does not produce any plotted output; it simply ends the output of plot data from PEPSUB for the duration of the run. These commands may cause difficulty at the end of execution; when an S or T command is given the program assumes that plotted output may still be produced. One reasonable sequence, however, would be in a run from a teletype, where the CLOSE command could be executed, and ABEL3 terminated using STOP instead of S or T. Then plotted output would be available on file and would not be dumped to the teletype. For full details on this, see Appendix A-4.

DONE not only shuts down plotted output but also shuts down ABEL3 and initiates processing of plotted information. Its affect is similar to an S or T command in the core routine.

MINIPLLOT and PEPSUB were designed for parallel use.

See separate documentation for explanations of these routines if desired. A slightly modified version of PEPSUB, available 9/15/77, could be "hardwired" to replace the version of the routine presently employed by ABEL3. This necessitates changes in the statements in the 11000-12000 block in addition to changes in the 9000-10000 block of instructions.

The plot setup routine performs a variety of functions. Axis labels, titles, and plot symbols are set, and options regarding how the absorption region data will be plotted are set by the user. The heart of this section, however, is the scaling routine which determines the Y axis size and scaling of the input data to fit that axis. Scaling is performed to give maximum possible magnification and detail to hard copy plot, and the user has no control over this scaling (although suggestions on how to modify the routine to obtain such control are given in VIII A). Both positive and negative data in either the emission or absorption region may be input, and correct scaling will result. The scale applicable to the emission region is the only scale output for a given plot; if different scaling is used for the absorption region, that scale must be determined from a printout of the data. There is no known way to overcome this inconvenience.

It should be noted that for all plotting the input data is transferred from the input major profile to two arrays labeled

X and Y. These arrays may be further manipulated by scaling and rearrangement so that they should not be used by other routines which a user might write.

To ease the plotting of data where a different symbol is employed in the emission and absorption regions, the plot setup routine automatically calls each plot routine twice, once to plot data from the emission region and once to plot data from the absorption region. This involves rearrangement of the X and Y arrays which complicated the use of both MINIPLOT and PEPSUB from a coding viewpoint. The linkage routines for the automatic overlay appear on page 6-3 and 6-4, lines 140-175.

C. Subroutine Noise

The effect of this subroutine is to add pseudo-random noise to the input profile:

$$V(K3,J) = V(K3,J) + \text{noise.}$$

The BASIC random number generator produces numbers between 0 and

1. So the various options in the noise routine are used to scale

RND - 0.5

(individual random number minus 0.5 so that the effective noise range is ± 0.5) to a value appropriate to some given model for the noise behavior.

In option 1, where noise is independent of the data, if the noise is assigned a peak-to-peak value T, then

$$V(K3,J)(\text{noisy}) = V(K3,J)(\text{no noise}) + T*(\text{RND} - 0.5) .$$

In options 2 and 3, the noise is based on some peak value in the input profile. Take that peak value to be in zone or ring N (only data within the ring/zone region specified in the core routine is searched for a data maximum). The user specifies a signal to noise ratio in that ring or zone of Q. Since T is the peak-to-peak value of the noise,

$$\frac{V(K3,N)}{T} = Q$$

or, as T is actually what is sought in setting up noise generation

$$T = \frac{V(K3,N)}{Q} .$$

From here, the equation used in option 1 may be employed.

For the remaining options, noise is related to some power of the value of each data point. Option 24 is the general case where

$$\text{noise} \propto \text{signal}^x$$

where x is a variable. In option 4, $x=1$ (noise proportional to signal) and in option 14, $x=0.5$ (noise proportional to square root of signal). In all cases, the user has the choice, of scaling noise arbitrarily (as was done in option 1), or based on the signal to noise ratio of the point with maximum data value over the interval of rings or zones allowed. As options 4 and 14 simply hardwire the value for the exponent in the noise expression, an explanation of the general case will suffice. There is no limitation on what the value of the exponent may be.

When arbitrary scaling is chosen ("absolute basis" in the printout from the program) the user chooses a scale factor T and in contrast to previous options

$$V(K3,J)(\text{noisy}) = V(K3,J)(\text{no noise}) + T * V(K3,J)^x (\text{RND} - 0.5) .$$

T is input directly by the user, x is the power relating signal and noise, and $(\text{RND} - 0.5)$ generates the noise to be scaled.

When scaling is based on signal to noise ratio at the maximum data value, the user inputs the desired S/N, and the scale factor T is internally computed. Presume that the highest datum (thus the value used to compute T) appears in ring or zone J_0 . Then

$$\begin{aligned}\text{signal}(J_0) &= V(K3, J_0) \text{ (no noise)} \\ \text{noise}(J_0) &= \text{random factor} * T * V(K3, J_0)^x.\end{aligned}$$

Dividing these two equations,

$$\frac{S}{N} = \frac{V(K3, J_0)}{\text{random factor} * T * V(K3, J_0)^x}.$$

Taking the random factor as 1.0, T may be computed to be

$$T = \frac{V(K3, J_0)^{1-x}}{(S/N)}.$$

S/N is input in statement number 12200, and T is computed in statement 12215 (page 3-1), lines 54 and 57 respectively. This T is then applied as a scale factor as if it had been input by the user in the "arbitrary scaling" option. The S/N scaling choice is used to provide a convenient input of an analytically common quantity; the program then converts the S/N ratio to a computationally simpler form.

For example, Figure 15 in "Considerations for Implementing Spatially-Resolved Spectroscopy Using the Abel Inversion," Anal. Chem. **46**, 1519 (1976) could be produced (in the noise generation step) by using option 4 (noise proportional to signal), signal to noise scaling, and an optimum S/N of 100.

D. Subroutine Smooth

The smoothing routine produces an effect inverse to the noise routine--random fluctuations are averaged out of data in successive rings or zones. A three point smooth or "rolling average" is provided in this routine. Except for the first and last rings and zones, the smoothing process is

$$V(K3,J)_{\text{smoothed}} = \left[\frac{V(K3,J-1) + 2*V(K3,J) + V(K3,J+1)}{4} \right]_{\text{unsmoothed}}$$

so that the smoothed value is the unsmoothed value "tempered" with data from adjacent zones. At end points,

$$V(K3,J)_{\text{smoothed}} = \left[\frac{V(K3,J) + V(K3,J\pm 1)}{2} \right]_{\text{unsmoothed}}$$

where J+1 applies near a left hand boundary and J-1 applies to a right hand boundary.

VII. Interaction Syntax

Pages I-1 through I-26 show the syntactical details of interaction in the use of program ABEL3. An index appears below:

Item (Subroutine)	Starts on Page
Initialization	I-1
Timesharing Core Routine	I-2
Batch Mode	I-3
Construc	I-4
Forward	I-10
Noise	I-13
Shift	I-15
Abel	I-18
Print-Plot	I-20
Smooth	I-25
Wander	I-26

Some discussion will be given on the use of the core routine and interaction which is particularly in need of explanation. Most of the syntax is intended to be self-explanatory.

Within the syntactical listing for each subroutine, all options are executed in numerical order. In order to generate

this listing, several runs were performed and much use of subroutine Construc is not shown, even though it was used to set up the profiles for use with a particular routine. An appropriate way to use this section as a learning aid for the program may be as follows:

- (1) Become familiar (through reading previous sections) with the capabilities and uses of a given routine.
- (2) Find the item of interest as listed above and the explanation of that section given below.
- (3) Read through the syntax. If a troublesome point arises, check in the explanation section.
- (4) If a point seems unclear at this stage, run the program and watch what happens.

As of this writing, there is one known program bug, i.e. a situation where typing a command does not result in that command being executed. In subroutine Print-Plot, when Miniplot is called, there is one combination of calling parameters which prevents any plot from being produced: If the absorption region plot symbol is not distinct AND the absorption region scaling is not the same as the emission scaling, then no plot will appear. In all other cases (other plot option combinations in Miniplot, all combinations to PEPSUB, etc) any typed entry will result in either

- (a) the desired response, or
- (b) a diagnostic explaining why such a desired response cannot be executed.

There is, to the author's knowledge no combination of responses which can "crash" either the program or the computer due to user action. All "mistakes" are reversible; and if a crash does occur, the program (and BASIC if necessary) can always be recalled.

I-1. Initialization

This will show up automatically after a RUN command. For result of entering BATCH instead of TIME to the first question, see I-3. For reinitialization in mid-execution, see I-17, option 5. Note that in reinitializing, the random number generator cannot be affected.

The "last emission ring" is the number of the ring which is outermost in the emission region. For a totally emitting model, enter 50. For a totally absorbing model, enter 0. Noninteger entries are rejected. Negative entries are set to 0, entries greater than 50 are set to 50.

The transmittance profile protection flag (TPPF) prevents lateral to radial computation (subroutine 5) unless the lateral profile has been computed after the backlight profile was produced. If no backlight has been user-initiated, in all cases one is provided by default, but if the backlight is changed, the

TPPF prevents inversion until the lateral intensity profile is brought up to date. For most modeling, having the TPPF "on" is a good safety feature to aid in preventing improperly sequenced operations. If irregular backlight behavior is to be modeled, the TPPF may be turned "off".

I-2. The top section of the page (to the "Time: 4.950") is a full run where no plots using PEPSUB were generated. Had plots been made, the result of "Subroutine number=? S" would be as shown at the bottom of the page, and the PEPSUB plot production package would be automatically called.

Commands to the core routine are classifiable into three categories:

- (1) Positive integers
- (2) Nonpositive integers
- (3) Literals

When a positive integer is used, that number becomes the command issued, unless overridden by a literal. Thus an option number, profile number, etc. may be directly specified. Numerous examples may be found on all pages of individual option syntax details.

Nonpositive integers represent default values for answers to individual questions. In all cases except subroutine number (in which case there is no default), entering 0 gives the default

answer to an individual question. The defaults are tabulated for each subroutine in the program listing on page 0-5.

The numeral -1 in response to "Which option?", "Major profile?", or "Minor profile?" specifies that whatever option or profile was specified for a particular question in the previous call to a subroutine is also to be used as the response in the present call. This allows one to set up the options for one subroutine, use several others, then come back and have the earlier specified options ready to go in the first called subroutine without having to note what options were used. That is, -1 leaves unchanged an earlier answer to a single question, and is subroutine specific. In response to "What option?", "Major profile?", or "Minor profile?", -2 allows the change of default values from those given on page 0-5 to some user chosen value. This value is immediately employed in the current subroutine call.

A default answer to either of the ring/zone number questions is equivalent. If a default is given to the "first ring or zone number" question, the other ring/zone question is not asked. When "0" is entered, all rings or zones of the appropriate profiles are involved in the operations of the chosen subroutine "-1" specifies the emission region only, and "-2" the absorption region only.

There are five literal commands. The order in which they are interpreted and what they mean is as follows:

- E** If an E appears anywhere in the response to a core routine question, the question is reasked. Several examples can be found in the sample run, one on page I-19 among them.
- R** This particular subroutine call is being cancelled--go back to the first core routine question. This allows an escape from any of the six core routine questions. See page I-2.
- S or T** Terminates execution and, if appropriate, starts PEPSUB plot output. Note: Do NOT terminate a run by typing the word STOP; doing so will destroy all plotted data.
- D** For all subsequent questions, employ the default (0) answer. This must be used in conjunction with a numeral. An example where subroutine 1 is called with all default parameters is shown on page I-2. A related example appears at the top of I-8.

I-3. This page details use of Abel3 in batch mode. Note that a run identifier is entered to assist in labeling the output. After the identifier is entered, initialization is the same as in timeshared mode. Input to all the subroutine is the same in timeshared and batch modes. The core routine, however, is slightly different in use in the two modes.

In batch mode, no literal commands may be given. All the numerical commands may be used. The six core routine

responses are placed on one card in the same order as in timeshare mode, with the numbers separated by commas. The runs shown on page I-3 are identical to those on page I-2 except that batch mode is employed. Note specifically that a run is terminated by entering

0,0,0,0,0,0 .

To obtain PEPSUB plots produced within a batch run, an interactive run at a PEP terminal can be started and the commands entered

```
@ASG,A PLOT.  
@ADD,P PLOT.
```

See PEPSUB documentation for further details. Particularly note comments about preserving plot information past 4:30 A.M. the day following execution.

Further syntactical details are, in order, the execution of the full list of options in the subroutines. For each option call, the order is

- (1) core routine calling sequence
- (2) echo of subroutine calling parameters (here defaults have been translated into profile numbers, etc.)
- (3) interaction from execution of the subroutine and option.

Comments which may clarify some of this interaction are as follows:

- (1) These were run interactively, all output could have been obtained in batch mode were this desired.

I-4. Note use of defaults on ring and zone number specifications to obtain desired operating regions. Compare affected rings and zones among options 1, 2, and 3.

I-5 and I-6. Options 5, 7, and 9: Entry of a ring or zone number falling outside the bounds specified in the core routine terminates the option.

I-9. Options numbered up to 34 are available. If the option number is N and $N \geq 20$, the options executed are option 20 immediately followed by option $N-20$.

I-10. In subroutine 2, if the user has not constructed a backlight intensity profile (profile 4) prior to calling the subroutine a profile will automatically be generated and a diagnostic describing the profile printed. Note that in options 2 and 3, the emission/absorption boundary serves to limit calculational range, i.e. if the boundary is in ring 25, option 2 is called, and the core routine specifies rings 30-35 for computation, no calculations will be performed. In options 12

and 13, the boundary is ignored in calculation. This allows segregation of absorption and emission effects on line profiles.

I-17. Subroutine 4 option 5 (reinitialization) affects all profiles, rings, and zones. Thus input to the last four core routine questions can be defaults, or anything else.

I-18. The Abel Inversion routine, options 2 and 3, ignores the emission/absorption boundary, while options 1 and 4 enforce the boundary. No reverse analogues to subroutine 2, options 2 and 3, exist. Again, calculations affect only the zones or rings specified.

In option 2, note that there is a choice between putting output to profile 6, the computed emission/absorption profile or profile 7, the absorption uncompensated emission/absorption profile. All other options put output into profile 6.

I-20 and I-22. Note what scaling options were used and how the plots appear in consequence. A listing of data would be necessary to determine what scale is applicable to the absorption region in the plot on page I-22. Due to the bug mentioned above, use of a separate plot symbol for the absorption region is recommended when using Miniplot. Any combination of plot options will work with Pepsab.

I-23. After entering subroutine number 12, the output line should read "Illegal subroutine number. Try again." The line is correct in the program, and the reason for this error is unknown.

Output from Pepsub showing the results of calculation in subroutine 2, option 1, with 100% transmittance being full scale in the absorption region of the profile, appears on page I-28.

I-26. In option 2, the "centrally peaked" distribution is indeed very steeply peaked. For maximum zonal wander of five zones, the number of sparks fired into each zone is:

No shift	36
±1 zones	25 (each sign)
±2 zones	6 (each sign)
±3 zones	2 (each sign)
±4 zones	1 (each sign)
±5 zones	1 (each sign)
Total:	106 sparks

Where the number centered in each zone is

$$\text{Int}\left(\frac{M}{N}\right)^2, \quad N \geq 1$$

$$(M+1)^2, \quad N = 0$$

M = maximum wander

N = number of zones displaced from unshifted position

Int = integer part of $(M/N)^2$.

For the maximum allowed wander (± 50 zones), this means the distribution is

No shift	2601
± 1 zone	2500 (each sign)
± 2 zones	625 (each sign)
± 3 zones	277 (each sign)

•
•
•
for a total of 10685 sparks with 71% centered in
the central three zones.

I-1

RUN

ABELJ 20:03:05 15 OCT 77

BATCH OR TIMESHARE RUN: INPUT 'BATCH' OR 'TIME' OR JOB ABORTS
? TIME
DO YOU WISH TO RANDOMIZE? '1' OR 'YES' OR 'Y' IS AFFIRMATIVE.
ALL OTHER RESPONSES ARE NEGATIVE.? N
HOW MANY RANDOM NUMBERS DO YOU WANT TO SKIP? 4
WHAT IS SPATIAL ZONE SIZE IN MICRONS? 50
WHAT IS LAST EMISSION RING? 25
SHOULD THE TRANSMITTANCE PROFILE PROTECTION FLAG BE ON—
RECOMMENDED THAT IT BE ON.
ENTER 'ON' OR 'OFF' YOUR CHOICE? ON
SHOULD PROFILE 8 BE AUTOMATICALLY CONSTRUCTED? YES

I-2

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 2
 MAJOR PROFILE INVOLVED=? 3E
 MAJOR PROFILE INVOLVED=? 3
 SECONDARY PROFILE INVOLVED=? R

SUBROUTINE NUMBER=? 1
 WHICH OPTION? -1
 MAJOR PROFILE INVOLVED=? 0
 SECONDARY PROFILE INVOLVED=? -2
 NEW DEFAULT SECONDARY PROFILE NUMBER FOR SUBROUTINE CONSTRUC
 ? 19
 FIRST ZONE OR RING NUMBER=? 2
 LAST (OUTER) ZONE OR RING NUMBER=? 20R

SUBROUTINE NUMBER=? 1D

IN SUBROUTINE CONSTRUC OPTION 4 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 19
 YOU ARE CONSTRUCTING AN HOMOGENEOUS U.C. RADIAL EMISSION PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM RELATIVE EMISSION VALUE IS=? 400

SUBROUTINE NUMBER=? S

TIME : 4.950

>

SUBROUTINE NUMBER=? S

FILE HAS BEEN CLOSED
 EXIT FROM BASIC

QADD,P PLOT.

TIME : 7.202

UNIVAC BASIC 20:10:53 15 OCT 77

I-3

PLEASE?
 >OLD:ABEL3
 >RUN

ABEL3 20:13:22 15 OCT 77

BATCH OR TIMESHARE RUN? INPUT 'BATCH' OR 'TIME' OR JOB ABORTS
 ? BATCH
 BATCH RUN ACTIVE.
 RUN IDENTIFIER INPUT? DEMORUN ON BATCH MODE
 DO YOU WISH TO RANDOMIZE? '1' OR 'YES' OR 'Y' IS AFFIRMATIVE.
 ALL OTHER RESPONSES ARE NEGATIVE.? 2
 HOW MANY RANDOM NUMBERS DO YOU WANT TO SKIP? 2
 WHAT IS SPATIAL ZONE SIZE IN MICRONS? 50
 WHAT IS LAST EMISSION RING? 25
 SHOULD THE TRANSMITTANCE PROFILE PROTECTION FLAG BE ON--
 RECOMMENDED THAT IT BE ON.
 ENTER 'ON' OR 'OFF' YOUR CHOICE? ON
 SHOULD PROFILE 8 BE AUTOMATICALLY CONSTRUCTED? YES

? 1.0.0.0.0.0

IN SUBROUTINE CONSTRUCT OPTION 4 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 11
 YOU ARE CONSTRUCTING AN HOMOGENEOUS U.C. RADIAL EMISSION PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM RELATIVE EMISSION VALUE IS=? 400

? 0.0.0.0.0.0

TIME : 4.467

>

0.0.0.0.0.0

FILE HAS BEEN CLOSED
 NO EXIT FROM BASIC
 THIS SHOULD BE THE LAST RETURN FROM THE PEP SUBROUTINE

TIME : 7.515

>

I-4

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 1
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? 0

IN SUBROUTINE CONSTRUCT OPTION 1 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 11
 YOU ARE CONSTRUCTING AN ON-AXIS GAUSSIAN U.C. RADIAL EMISSION
 PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM RELATIVE EMISSION VALUE IS=? 400
 GAUSSIAN HALF WIDTH AT HALF HEIGHT? 5

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 2
 MAJOR PROFILE INVOLVED=? 2
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? -1

IN SUBROUTINE CONSTRUCT OPTION 2 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 25
 PROFILE NUMBERS= 2 11
 YOU ARE CONSTRUCTING AN OFF-AXIS GAUSSIAN U.C. RADIAL ABSORPTION
 PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM EPSILON.CONCENTRATION IS=? 10
 GAUSSIAN CENTERED IN ZONE OR RING? 15
 GAUSSIAN HALF WIDTH AT HALF HEIGHT? 5

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 3
 MAJOR PROFILE INVOLVED=? 3
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? -2

IN SUBROUTINE CONSTRUCT OPTION 3 WILL BE
 PERFORMED ON RINGS OR ZONES 26 TO 50
 PROFILE NUMBERS= 3 11
 YOU ARE CONSTRUCTING AN ELLIPSOIDAL LATERAL INTENSITY PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM OBSERVED INTENSITY IS=? 100
 ZONE OR RING IN WHICH ELLIPSE FALLS TO ZERO? 40

SUBROUTINE NUMBER=? E

I-5

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 4
 MAJOR PROFILE INVOLVED=? 4
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? 1
 LAST (OUTER) ZONE OR RING NUMBER=? 25

IN SUBROUTINE CONSTRUCT OPTION 4 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 25
 PROFILE NUMBERS= 4 11
 YOU ARE CONSTRUCTING AN HOMOGENEOUS U.C. BACKLIGHT PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM NON-ABSORBED VALUE IS=? 100

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 5
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? 1
 LAST (OUTER) ZONE OR RING NUMBER=? 25

IN SUBROUTINE CONSTRUCT OPTION 5 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 25
 PROFILE NUMBERS= 1 11
 YOU HAVE DECIDED TO INPUT SELECTED RELATIVE EMISSION VALUE VALUES
 IN THE U.C. RADIAL EMISSION PROFILE.
 ZONE OR RING=? 4
 VALUE=? 22
 ZONE OR RING=? 17
 VALUE=? 555
 ZONE OR RING=? 3
 VALUE=? 22.279
 ZONE OR RING=? 26

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 4
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? 1
 LAST (OUTER) ZONE OR RING NUMBER=? 5

IN SUBROUTINE CONSTRUCT OPTION 4 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 5
 PROFILE NUMBERS= 1 11
 YOU HAVE DECIDED TO INPUT ALL POSSIBLE RELATIVE EMISSION VALUE
 VALUES
 IN THE U.C. RADIAL EMISSION PROFILE.
 INPUT 5 VALUES, 1 PER LINE.
 ZONE OR RING 1 VALUE=? 2
 ZONE OR RING 2 VALUE=? 4
 ZONE OR RING 3 VALUE=? 4
 ZONE OR RING 4 VALUE=? 8
 ZONE OR RING 5 VALUE=? 10

SUBROUTINE NUMBER=? E

I-6

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SUBROUTINE NUMBER=? 1
WHICH OPTION? 7
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 0
FIRST ZONE OR RING NUMBER=? 1
LAST (OUTER) ZONE OR RING NUMBER=? 25

IN SUBROUTINE CONSTRUC OPTION 7 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 25
PROFILE NUMBERS= 1 11
YOU HAVE DECIDED TO SCALE SELECTED RELATIVE EMISSION VALUE VALUES
IN THE U.C. RADIAL EMISSION PROFILE.
ZONE OR RING=? 13
VALUE=? 1.5
ZONE OR RING=? 14
VALUE=? 1.6
ZONE OR RING=? 28

SUBROUTINE NUMBER=? 1
WHICH OPTION? 8
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 0
FIRST ZONE OR RING NUMBER=? 1
LAST (OUTER) ZONE OR RING NUMBER=? 5

IN SUBROUTINE CONSTRUC OPTION 8 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 5
PROFILE NUMBERS= 1 11
YOU HAVE DECIDED TO SCALE ALL POSSIBLE RELATIVE EMISSION VALUE
VALUES
IN THE U.C. RADIAL EMISSION PROFILE.
INPUT 5 VALUES, 1 PER LINE.
ZONE OR RING 1 VALUE=? 1.1
ZONE OR RING 2 VALUE=? 1.2
ZONE OR RING 3 VALUE=? 1.3
ZONE OR RING 4 VALUE=? 1.4
ZONE OR RING 5 VALUE=? 1.5

SUBROUTINE NUMBER=? 1
WHICH OPTION? 9
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 0
FIRST ZONE OR RING NUMBER=? 1
LAST (OUTER) ZONE OR RING NUMBER=? 25

IN SUBROUTINE CONSTRUC OPTION 9 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 25
PROFILE NUMBERS= 1 11
YOU HAVE DECIDED TO ADD TO SELECTED RELATIVE EMISSION VALUE VALUES
IN THE U.C. RADIAL EMISSION PROFILE.
ZONE OR RING=? 2
VALUE=? 15
ZONE OR RING=? -2

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I-7

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SUBROUTINE NUMBER=? 1
WHICH OPTION? 10
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 0
FIRST ZONE OR RING NUMBER=? 1
LAST (OUTER) ZONE OR RING NUMBER=? 25E
LAST (OUTER) ZONE OR RING NUMBER=? 5

IN SUBROUTINE CONSTRUC OPTION 10 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 5
PROFILE NUMBERS= 1 11
YOU HAVE DECIDED TO ADD TO ALL POSSIBLE RELATIVE EMISSION VALUE
VALUES
IN THE U.C. RADIAL EMISSION PROFILE.
INPUT 5 VALUES, 1 PER LINE.
ZONE OR RING 1 VALUE=? 3
ZONE OR RING 2 VALUE=? 3
ZONE OR RING 3 VALUE=? 3
ZONE OR RING 4 VALUE=? 3
ZONE OR RING 5 VALUE=? 3

SUBROUTINE NUMBER=? 11
ILLEGAL SUBROUTINE NUMBER. TRY AGAIN.
SUBROUTINE NUMBER=? 1
WHICH OPTION? 11
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 2
FIRST ZONE OR RING NUMBER=? 0

IN SUBROUTINE CONSTRUC OPTION 11 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 2
OVER THE APPLICABLE ZONES OR RINGS, THE POSITIVE U.C. RADIAL ABSORPTION
PROFILE
WILL BE ADDED TO THE U.C. RADIAL EMISSION PROFILE.
THE RESULT IS STORED IN PROFILE 1, THE U.C. RADIAL EMISSION
PROFILE
THE UNCHANGED PROFILE IS NUMBER 2.

SUBROUTINE NUMBER=? 1
WHICH OPTION? 12
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 2
FIRST ZONE OR RING NUMBER=? 0

IN SUBROUTINE CONSTRUC OPTION 12 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 2
OVER THE APPLICABLE ZONES OR RINGS, THE NEGATIVE U.C. RADIAL ABSORPTION
PROFILE
WILL BE ADDED TO THE U.C. RADIAL EMISSION PROFILE.
THE RESULT IS STORED IN PKOFILE 1, THE U.C. RADIAL EMISSION
PROFILE
THE UNCHANGED PROFILE IS NUMBER 2.

SUBROUTINE NUMBER=? E

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I-8

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 13
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 00

IN SUBROUTINE CONSTRUC OPTION 13 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 11
 YOU ARE SCALING EVERY APPLICABLE POINT IN THE U.C. RADIAL EMISSION
 PROFILE
 BY WHATEVER VALUE YOU INPUT.
 WHAT IS THE SCALE FACTOR? 3.14159

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 14
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 2
 FIRST ZONE OR RING NUMBER=? 0

IN SUBROUTINE CONSTRUC OPTION 14 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 2
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
 WILL BE CROSS-MULTIPLIED WITH PROFILE 2,
 THE U.C. RADIAL ABSORPTION PROFILE. THE RESULTS ARE IN PROFILE
 1.

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 20
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 00

IN SUBROUTINE CONSTRUC OPTION 20 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 11
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE IS BEING CLEARED
 FROM ZONE OR RING NUMBER 1 TO ZONE OR RING NUMBER 50.

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 21
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 00

IN SUBROUTINE CONSTRUC OPTION 21 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 11
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE IS BEING CLEARED
 FROM ZONE OR RING NUMBER 1 TO ZONE OR RING NUMBER 50.
 YOU ARE CONSTRUCTING AN ON-AXIS GAUSSIAN U.C. RADIAL EMISSION
 PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM RELATIVE EMISSION VALUE IS=? 1000
 GAUSSIAN HALF WIDTH AT HALF HEIGHT? 5

SUBROUTINE NUMBER=? E

I-9

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 2
 MAJOR PROFILE INVOLVED=? 2
 SECONDARY PROFILE INVOLVED=? E
 SECONDARY PROFILE INVOLVED=? R

SUBROUTINE NUMBER=? 1
 WHICH OPTION? 22
 MAJOR PROFILE INVOLVED=? 2
 SECONDARY PROFILE INVOLVED=? OD

IN SUBROUTINE CONSTRU OPTION 22 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 2 11
 PROFILE 2, THE U.C. RADIAL ABSORPTION PROFILE IS BEING CLEARED
 FROM ZONE OR RING NUMBER 1 TO ZONE OR RING NUMBER 50.
 YOU ARE CONSTRUCTING AN OFF-AXIS GAUSSIAN U.C. RADIAL ABSORPTION
 PROFILE
 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
 MAXIMUM EPSILON CONCENTRATION IS=? 5
 GAUSSIAN CENTERED IN ZONE OR RING? 30
 GAUSSIAN HALF WIDTH AT HALF HEIGHT? 5
 SUBROUTINE NUMBER=? E

I-10

SUBROUTINE NUMBER=? 2
WHICH OPTION? 1
MAJOR PROFILE INVOLVED=? 8
SECONDARY PROFILE INVOLVED=? 00

IN SUBROUTINE FORWARD OPTION 1 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 8 2
IN FORWARD, PROFILE 8, THE U.C. EMISSION/ABSORPTION PROFILE
WAS USED AS AN INPUT RADIAL EMISSION PROFILE.
IN FORWARD, PROFILE 8, THE U.C. EMISSION/ABSORPTION PROFILE
WAS USED AS AN INPUT RADIAL ABSORPTION PROFILE.
OPERATING LIMITS WERE ZONES AND RINGS 1 TO 50.
OPTION 1 WAS EXECUTED IN FORWARD.
OPERATION DESCRIPTION:
COMPLETE RADIAL TO LATERAL EMISSION/ABSORPTION CALCULATION PERFORMED.

SUBROUTINE NUMBER=? 2
WHICH OPTION? 2
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 20

IN SUBROUTINE FORWARD OPTION 2 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 2
IN FORWARD, PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WAS USED AS AN INPUT RADIAL EMISSION PROFILE.
OPERATING LIMITS WERE ZONES AND RINGS 1 TO 50.
OPTION 2 WAS EXECUTED IN FORWARD.
OPERATION DESCRIPTION:
RADIAL EMISSION TO LATERAL INTENSITY CALCULATION PERFORMED.

SUBROUTINE NUMBER=? 2
WHICH OPTION? 12
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 20

IN SUBROUTINE FORWARD OPTION 12 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 2
EMISSION/ABSORPTION BOUNDARY AS SET PREVIOUSLY
WILL BE IGNORED IN FORWARD.
IN FORWARD, PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WAS USED AS AN INPUT RADIAL EMISSION PROFILE.
OPERATING LIMITS WERE ZONES AND RINGS 1 TO 50.
OPTION 2 WAS EXECUTED IN FORWARD.
OPERATION DESCRIPTION:
RADIAL EMISSION TO LATERAL INTENSITY CALCULATION PERFORMED.

SUBROUTINE NUMBER=? E

I-11

SUBROUTINE NUMBER=? 2
WHICH OPTION? 3
MAJOR PROFILE INVOLVED=? 2D

IN SUBROUTINE FORWARD OPTION 3 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 2
IN FORWARD, PROFILE 2, THE U.C. RADIAL ABSORPTION PROFILE
WAS USED AS AN INPUT RADIAL ABSORPTION PROFILE.
OPERATING LIMITS WERE ZONES AND RINGS 1 TO 50 .
OPTION 3 WAS EXECUTED IN FORWARD.
OPERATION DESCRIPTION:
RADIAL ABSORPTION TO TRANSMITTANCE PROFILE CALCULATION PERFORMED.

SUBROUTINE NUMBER=? 2
WHICH OPTION? 13
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 2D

IN SUBROUTINE FORWARD OPTION 13 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 2
EMISSION/ABSORPTION BOUNDARY AS SET PREVIOUSLY
WILL BE IGNORED IN FORWARD.
IN FORWARD, PROFILE 2, THE U.C. RADIAL ABSORPTION PROFILE
WAS USED AS AN INPUT RADIAL ABSORPTION PROFILE.
OPERATING LIMITS WERE ZONES AND RINGS 1 TO 50 .
OPTION 3 WAS EXECUTED IN FORWARD.
OPERATION DESCRIPTION:
RADIAL ABSORPTION TO TRANSMITTANCE PROFILE CALCULATION PERFORMED.

SUBROUTINE NUMBER=? 2
WHICH OPTION? 4
MAJOR PROFILE INVOLVED=? 3
SECONDARY PROFILE INVOLVED=? 2D

IN SUBROUTINE FORWARD OPTION 4 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 3 2
IN FORWARD, PROFILE 2, THE U.C. RADIAL ABSORPTION PROFILE
WAS USED AS AN INPUT RADIAL ABSORPTION PROFILE.
OPERATING LIMITS WERE ZONES AND RINGS 1 TO 50 .
OPTION 4 WAS EXECUTED IN FORWARD.
OPERATION DESCRIPTION:
INTENSITY PROFILE IN PROFILE 3, THE LATERAL INTENSITY PROFILE
WAS ATTENUATED ASSUMING AN ABSORBER AS DESCRIBED
IN PROFILE 2 ABOVE.

SUBROUTINE NUMBER=? E

I-12

SUBROUTINE NUMBER=? 3
WHICH OPTION? 1
MAJOR PROFILE INVOLVED=? 10

IN SUBROUTINE NOISE OPTION 1 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 9
THIS IS THE NOISE ADDITION SUBROUTINE.
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.
THE NOISELESS DATA INPUT IS SAVED IN PROFILE 9,
THE NOISE SCRATCH REGISTER PROFILE.
IN NOISE, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
OPTION 1 WILL BE EXECUTED.
IN ABSOLUTE UNITS, WHAT IS PEAK-TO-PEAK NOISE VALUE? 14

SUBROUTINE NUMBER=? 3
WHICH OPTION? 2
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 19
FIRST ZONE OR RING NUMBER=? 0

IN SUBROUTINE NOISE OPTION 2 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 19
THIS IS THE NOISE ADDITION SUBROUTINE.
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.
THE NOISELESS DATA INPUT IS SAVED IN PROFILE 19,
THE SCRATCH REGISTER B PROFILE.
IN NOISE, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
OPTION 2 WILL BE EXECUTED.
NOISE BASED ON MAXIMUM EMISSION REGION DATA VALUE.
WHAT IS SIGNAL TO NOISE RATIO AT HIGHEST DATA VALUE? 100

SUBROUTINE NUMBER=? 3
WHICH OPTION? 3
MAJOR PROFILE INVOLVED=? 10

IN SUBROUTINE NOISE OPTION 3 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 9
THIS IS THE NOISE ADDITION SUBROUTINE.
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.
THE NOISELESS DATA INPUT IS SAVED IN PROFILE 9,
THE NOISE SCRATCH REGISTER PROFILE.
IN NOISE, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
OPTION 3 WILL BE EXECUTED.
NOISE BASED ON MAXIMUM ABSORPTION REGION DATA VALUE.
WHAT IS SIGNAL TO NOISE RATIO AT HIGHEST DATA VALUE? 100

I-13

SUBROUTINE NUMBER=? 3
WHICH OPTION? 4
MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE NOISE OPTION 4 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 9
THIS IS THE NOISE ADDITION SUBROUTINE.
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.
THE NOISELESS DATA INPUT IS SAVED IN PROFILE 9,
THE NOISE SCRATCH REGISTER PROFILE.
IN NOISE, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
OPTION 4 WILL BE EXECUTED.
SCALING CHOICE. DO YOU WISH TO SCALE NOISE ON AN
ABSOLUTE BASIS OR ON AN OPTIMUM SIGNAL TO NOISE RATIO BASIS?
ENTER 'ABS' OR 'SN'.? ABS
NOISE IS PROPORTIONAL TO THE 1 POWER OF THE DATA,
SCALED BY A FACTOR OF? .01

SUBROUTINE NUMBER=? 3
WHICH OPTION? 4
MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE NOISE OPTION 4 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 9
THIS IS THE NOISE ADDITION SUBROUTINE.
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.
THE NOISELESS DATA INPUT IS SAVED IN PROFILE 9,
THE NOISE SCRATCH REGISTER PROFILE.
IN NOISE, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
OPTION 4 WILL BE EXECUTED.
SCALING CHOICE. DO YOU WISH TO SCALE NOISE ON AN
ABSOLUTE BASIS OR ON AN OPTIMUM SIGNAL TO NOISE RATIO BASIS?
ENTER 'ABS' OR 'SN'.? SN
NOISE IS PROPORTIONAL TO THE 1 POWER OF THE DATA,
WITH MAXIMUM SIGNAL TO NOISE RATIO? 100

SUBROUTINE NUMBER=? E

I-14

SUBROUTINE NUMBER=? 3
WHICH OPTION? 14
MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE NOISE OPTION 14 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 9
THIS IS THE NOISE ADDITION SUBROUTINE.
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.
THE NOISELESS DATA INPUT IS SAVED IN PROFILE 9,
THE NOISE SCRATCH REGISTER PROFILE.
IN NOISE, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
OPTION 14 WILL BE EXECUTED.
SCALING CHOICE. DO YOU WISH TO SCALE NOISE ON AN
ABSOLUTE BASIS OR ON AN OPTIMUM SIGNAL TO NOISE RATIO BASIS?
ENTER 'ABS' OR 'SN'.? SN
NOISE IS PROPORTIONAL TO THE .5 POWER OF THE DATA,
WITH MAXIMUM SIGNAL TO NOISE RATIO? 100

SUBROUTINE NUMBER=? 3
WHICH OPTION? 245
MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE NOISE OPTION 245 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 9
ILLEGAL OR INCOMPATIBLE OPTION IN NOISE ROUTINE.
OPTION 245 WAS CHOSEN.
IF OPTION 2 OR 3 WERE USED, CHECK FOR THE ABSENCE OF
EITHER THE EMISSION REGION OR THE ABSORPTION REGION.
RETURN AND TRY AGAIN.

SUBROUTINE NUMBER=? 3
WHICH OPTION? 24
MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE NOISE OPTION 24 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 9
THIS IS THE NOISE ADDITION SUBROUTINE.
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.
THE NOISELESS DATA INPUT IS SAVED IN PROFILE 9,
THE NOISE SCRATCH REGISTER PROFILE.
IN NOISE, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
OPTION 24 WILL BE EXECUTED.
UPON WHAT POWER OF THE DATA DOES NOISE DEPEND? 2
SCALING CHOICE. DO YOU WISH TO SCALE NOISE ON AN
ABSOLUTE BASIS OR ON AN OPTIMUM SIGNAL TO NOISE RATIO BASIS?
ENTER 'ABS' OR 'SN'.? SN
NOISE IS PROPORTIONAL TO THE 2 POWER OF THE DATA,
WITH MAXIMUM SIGNAL TO NOISE RATIO? 100

I-15

SUBROUTINE NUMBER=? 4
WHICH OPTION? 1
MAJOR PROFILE INVOLVED=? 3D

IN SUBROUTINE SHIFT OPTION 1 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 3 10
BY HOW MANY ZONES DO YOU WISH TO SHIFT THE PROFILE? 5
PROFILE 3, THE LATERAL INTENSITY PROFILE
WILL BE SHIFTED 5 RINGS OR ZONES.
UNSHIFTED PROFILE STORED IN PROFILE NUMBER 13
EMISSION-ABSORPTION BOUNDARY FIXED AND EMPLOYED.
BACKLIGHT PROFILE, NUMBER 4, HAS BEEN SHIFTED.
PROFILE 10, THE BACKGROUND INTENSITY PROFILE
WILL BE SHIFTED 5 RINGS OR ZONES.
UNSHIFTED PROFILE STORED IN PROFILE NUMBER 14
EMISSION-ABSORPTION BOUNDARY FIXED AND EMPLOYED.

SUBROUTINE NUMBER=? 4
WHICH OPTION? 11
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 0D

IN SUBROUTINE SHIFT OPTION 11 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 10
BY HOW MANY ZONES DO YOU WISH TO SHIFT THE PROFILE? -5
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL BE SHIFTED -5 RINGS OR ZONES.
NO REFLECTION OR BACKFILLING WILL OCCUR.
UNSHIFTED PROFILE STORED IN PROFILE NUMBER 13
EMISSION-ABSORPTION BOUNDARY FIXED AND EMPLOYED.

SUBROUTINE NUMBER=? 4
WHICH OPTION? 2
MAJOR PROFILE INVOLVED=? 1
SECONDARY PROFILE INVOLVED=? 0D

IN SUBROUTINE SHIFT OPTION 2 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 1 10
BY HOW MANY ZONES DO YOU WISH TO SHIFT THE PROFILE? 5
PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
WILL BE SHIFTED 5 RINGS OR ZONES.
M1 SHIFTED ALSO.
UNSHIFTED PROFILE STORED IN PROFILE NUMBER 13

SUBROUTINE NUMBER=? 4
WHICH OPTION? 12
MAJOR PROFILE INVOLVED=? 1D

I-16

IN SUBROUTINE SHIFT OPTION 12 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 10
 BY HOW MANY ZONES DO YOU WISH TO SHIFT THE PROFILE? -5
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
 WILL BE SHIFTED -5 RINGS OR ZONES.
 NO REFLECTION OR BACKFILLING WILL OCCUR.
 M1 SHIFTED ALSO.
 UNSHIFTED PROFILE STORED IN PROFILE NUMBER 13

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 3
 MAJOR PROFILE INVOLVED=? 10

IN SUBROUTINE SHIFT OPTION 3 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 10
 BY HOW MANY ZONES DO YOU WISH TO SHIFT THE PROFILE? 5
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
 WILL BE SHIFTED 5 RINGS OR ZONES.
 M1 IGNORED.
 UNSHIFTED PROFILE STORED IN PROFILE NUMBER 13

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 13
 MAJOR PROFILE INVOLVED=? 10

IN SUBROUTINE SHIFT OPTION 13 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 10
 BY HOW MANY ZONES DO YOU WISH TO SHIFT THE PROFILE? 2
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
 WILL BE SHIFTED 2 RINGS OR ZONES.
 NO REFLECTION OR BACKFILLING WILL OCCUR.
 M1 IGNORED.
 UNSHIFTED PROFILE STORED IN PROFILE NUMBER 13

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 4
 MAJOR PROFILE INVOLVED=? 10

IN SUBROUTINE SHIFT OPTION 4 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 10
 UNSHIFT PRESENT PROFILE(S).
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
 IS BEING UNSHIFTED, AS IS M1.

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 4
 MAJOR PROFILE INVOLVED=? 30

I-17

IN SUBROUTINE SHIFT OPTION 4 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 3 10
 UNSHIFT PRESENT PROFILE(S).
 PROFILE 3, THE LATERAL INTENSITY PROFILE
 IS BEING UNSHIFTED, AS IS M1.
 PROFILE 10, THE BACKGROUND INTENSITY PROFILE
 IS BEING UNSHIFTED, AS IS M1.

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 5D

IN SUBROUTINE SHIFT OPTION 5 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 3 10
 IN SHIFT, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
 REINITIALIZING SYSTEM
 WHAT IS SPATIAL ZONE SIZE IN MICRONS? 50
 WHAT IS LAST EMISSION RING? 25
 SHOULD THE TRANSMITTANCE PROFILE PROTECTION FLAG BE ON--
 RECOMMENDED THAT IT BE ON.
 ENTER 'ON' OR 'OFF' YOUR CHOICE? ON
 SHOULD PROFILE 8 BE AUTOMATICALLY CONSTRUCTED? YES

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 6D

IN SUBROUTINE SHIFT OPTION 4 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 3 10
 IN SHIFT, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
 RESET LAST EMISSION RING NUMBER.
 YOUR CHOICE? 30

SUBROUTINE NUMBER=? E

I-18

SUBROUTINE NUMBER=? 5
WHICH OPTION? 1
MAJOR PROFILE INVOLVED=? 3D

IN SUBROUTINE ABEL OPTION 1 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 3 4
IN ABEL, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
THE LATERAL TO RADIAL INVERSION WILL BE PERFORMED.
PROFILE 3, THE LATERAL INTENSITY PROFILE
WILL BE USED AS AN INPUT LATERAL INTENSITY PROFILE.
PROFILE 4 IS THE BACKLIGHT INTENSITY PROFILE.
A FULL DREANS INVERSION WILL BE PERFORMED.
OUTPUT IS TO PROFILE NUMBER 4

SUBROUTINE NUMBER=? 5
WHICH OPTION? 2
MAJOR PROFILE INVOLVED=? 3
SECONDARY PROFILE INVOLVED=? 0
FIRST ZONE OR RING NUMBER=? -1

IN SUBROUTINE ABEL OPTION 2 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 30
PROFILE NUMBERS= 3 4
IN ABEL, RINGS OR ZONES 1 TO 30 ARE AFFECTED.
THE LATERAL TO RADIAL INVERSION WILL BE PERFORMED.
PROFILE 3, THE LATERAL INTENSITY PROFILE
WILL BE USED AS AN INPUT LATERAL INTENSITY PROFILE.
AN INVERSION WILL BE PERFORMED ASSUMING A PURELY EMITTING PROFILE.
OUTPUT WILL BE TO PROFILE 7 UNLESS YOU INPUT THE NUMERAL
4 IN RESPONSE TO THE NEXT QUESTION MARK.
? ABC
OUTPUT IS TO PROFILE NUMBER 7

SUBROUTINE NUMBER=? 5
WHICH OPTION? 3
MAJOR PROFILE INVOLVED=? 3
SECONDARY PROFILE INVOLVED=? 0
FIRST ZONE OR RING NUMBER=? -2

IN SUBROUTINE ABEL OPTION 3 WILL BE
PERFORMED ON RINGS OR ZONES 31 TO 50
PROFILE NUMBERS= 3 4
IN ABEL, RINGS OR ZONES 31 TO 50 ARE AFFECTED.
THE LATERAL TO RADIAL INVERSION WILL BE PERFORMED.
PROFILE 3, THE LATERAL INTENSITY PROFILE
WILL BE USED AS AN INPUT LATERAL INTENSITY PROFILE.
PROFILE 4 IS THE BACKLIGHT INTENSITY PROFILE.
INVERSION OF A PURELY ABSORBING PROFILE IS ASSUMED.
OUTPUT IS TO PROFILE NUMBER 4

SUBROUTINE NUMBER=? E

I-19

SUBROUTINE NUMBER=? 5
WHICH OPTION? 4
MAJOR PROFILE INVOLVED=? 4E
MAJOR PROFILE INVOLVED=? 3
SECONDARY PROFILE INVOLVED=? 2
FIRST ZONE OR RING NUMBER=? 0

IN SUBROUTINE ABEL OPTION 4 WILL BE
PERFORMED ON RINGS OR ZONES 1 TO 50
PROFILE NUMBERS= 3 2
IN ABEL, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
THE LATERAL TO RADIAL INVERSION WILL BE PERFORMED.
PROFILE 3, THE LATERAL INTENSITY PROFILE
WILL BE USED AS AN INPUT LATERAL INTENSITY PROFILE.
PROFILE 2, THE U.C. RADIAL ABSORPTION PROFILE
IS THE ASSUMED RADIAL ABSORPTION DISTRIBUTION.
THE LATERAL PROFILE OBSERVED IS ASSUMED TO HAVE BEEN
ATTENUATED BY THE ABSORBER IN PROFILE 2,
AND THE CALCULATIONS ARE DONE ACCORDINGLY.
OUTPUT IS TO PROFILE NUMBER 6

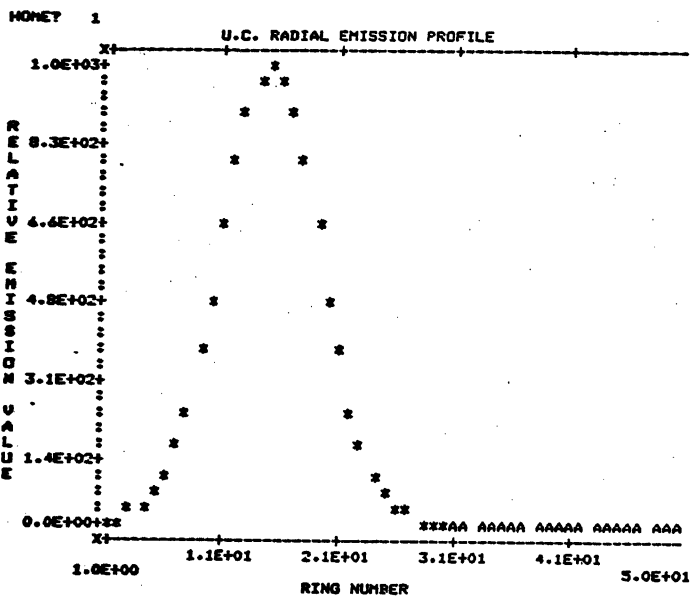
SUBROUTINE NUMBER=? E

I-20

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 1
 MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE PRINT-PLOT OPTION 1 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 1
 PLOT OPTIONS. SHOULD ABSORPTION REGION'S PLOT SYMBOL BE DISTINCT
 ? YES
 PLOT HAS 2 DIFFERENT SYMBOLS.
 SHOULD ABSORPTION REGION BE SCALED THE SAME AS THE EMISSION REGION
 ? YES

D) PLOT STATUS? NEW



NORMAL RETURN

SUBROUTINE NUMBER=? E

I-21

SUBROUTINE NUMBER=? 6
 WHICH OPTION? 2
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? -1

IN SUBROUTINE PRINT-PLOT OPTION 2 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 30
 PROFILE NUMBERS= 1 1
 A) ENABLE HARD COPY PLOTTING? NO

B) PLOT STATUS? NEW

NORMAL RETURN

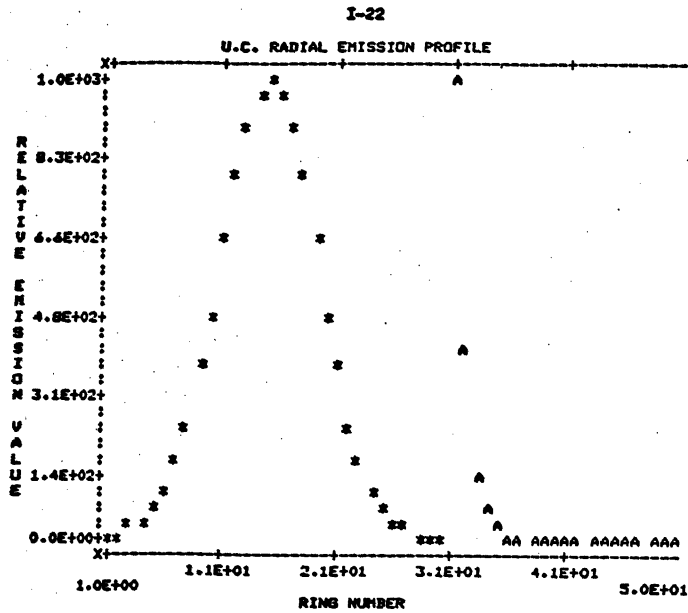
SUBROUTINE NUMBER=? 6
 WHICH OPTION? 3
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0D

IN SUBROUTINE PRINT-PLOT OPTION 3 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 1
 PLOT OPTIONS. SHOULD ABSORPTION REGION'S PLOT SYMBOL BE DISTINCT
 ? YES
 PLOT HAS 2 DIFFERENT SYMBOLS.
 SHOULD ABSORPTION REGION BE SCALED THE SAME AS THE EMISSION REGION
 ? NO

B) PLOT STATUS? NEE

B) PLOT STATUS? NEW

NONE? 1



NORMAL RETURN

D) PLOT STATUS? NEW

NORMAL RETURN

SUBROUTINE NUMBER=? 6
 WHICH OPTION? 10
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? 1
 LAST (OUTER) ZONE OR RING NUMBER=? 10

IN SUBROUTINE PRINT-PLOT OPTION 10 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 10
 PROFILE NUMBERS= 1 1
 HOME? 1

I-23

PROFILE 1, THE U.C. RADIAL EMISSION PROFILE IS PRINTED BELOW.

INDEX	RELATIVE EMISSION VALUE	LOG U(I,J)
1	4.3644025	.43992479
2	9.2265042	.96503717
3	18.45301	1.2660472
4	34.91322	1.5430148
5	42.499993	1.79588
6	105.84314	2.0246628
7	149.57553	2.2293632
8	257.02845	2.4099812
9	368.5473	2.5665168
10	499.99998	2.69897

SUBROUTINE NUMBER=? 12
 L SUBROUTINE NUMBER. TRY AGAIN.
 SUBROUTINE NUMBER=? E
 SUBROUTINE NUMBER=? 6
 WHICH OPTION? 10
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? 1
 LAST (OUTER) ZONE OR RING NUMBER=? 10

 IN SUBROUTINE PRINT-PLOT OPTION 10 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 10
 PROFILE NUMBERS= 1 1
 NONE?

I-24

1

PROFILE 1 , THE U.C. RADIAL EMISSION PROFILE IS PRINTED BELOW.

INDEX	RELATIVE EMISSION VALUE	LOG V(I,J)
1	4.3644025	.63992479
2	9.2265042	.96503717
3	18.45301	1.2660672
4	34.91522	1.5430148
5	62.499993	1.79588
6	105.84314	2.0246629
7	149.57553	2.2293632
8	257.02845	2.4099912
9	368.5673	2.5665168
10	499.99998	2.69897

SUBROUTINE NUMBER=? 4
 WHICH OPTION? 12
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? 1
 LAST (OUTER) ZONE OR RING NUMBER=? 5

IN SUBROUTINE PRINT-PLOT OPTION 12 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 5
 PROFILE NUMBERS= 1 1
 NONE? 1

PROFILE 1 , THE U.C. RADIAL EMISSION PROFILE IS PRINTED BELOW.

INDEX	RELATIVE EMISSION VALUE	LOG V(I,J)
1	4.3644025	.63992479
2	9.2265042	.96503717
3	18.45301	1.2660672
4	34.91522	1.5430148
5	62.499993	1.79588

D) PLOT STATUS? NEW

NORMAL RETURN

SUBROUTINE NUMBER=? E

I-25

SUBROUTINE NUMBER=? 7
 WHICH OPTION? 1
 MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE SMOOTH OPTION 1 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 12
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
 WILL BE SMOOTHED, USING A TRIANGULAR SMOOTHING FUNCTION.
 IN SMOOTH, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
 THE UNSMOOTHED PROFILE IS STORED IN
 PROFILE 12, THE SMOOTH SCRATCH REGISTER PROFILE

SUBROUTINE NUMBER=? 7
 WHICH OPTION? 2
 MAJOR PROFILE INVOLVED=? 1D

IN SUBROUTINE SMOOTH OPTION 2 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1 12
 PROFILE 1, THE U.C. RADIAL EMISSION PROFILE
 WILL BE SMOOTHED, USING A TRIANGULAR SMOOTHING FUNCTION.
 IN SMOOTH, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
 THE UNSMOOTHED PROFILE IS STORED IN
 PROFILE 12, THE SMOOTH SCRATCH REGISTER PROFILE
 EMISSION-ABSORPTION BOUNDARY BEING IGNORED DUE TO OPTION CHOICE.

SUBROUTINE NUMBER=? E

I-26

SUBROUTINE NUMBER=? 8
 WHICH OPTION? 1
 MAJOR PROFILE INVOLVED=? 1D

 IN SUBROUTINE WANDER OPTION 1 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 50
 PROFILE NUMBERS= 1
 SPARK WILL WANDER RANDOMLY.
 HOW MANY SPARKS DO YOU WANT? 225
 WHAT IS MAXIMUM ZONAL CHANNEL WANDER? 5
 225 SPARKS FIRED; OUTPUT TO PROFILE 1
 PREWANDER DATA IN PROFILE 13.

16

SUBROUTINE NUMBER=? 8
 WHICH OPTION? 2
 MAJOR PROFILE INVOLVED=? 1
 SECONDARY PROFILE INVOLVED=? 0
 FIRST ZONE OR RING NUMBER=? -1

IN SUBROUTINE WANDER OPTION 2 WILL BE
 PERFORMED ON RINGS OR ZONES 1 TO 30
 PROFILE NUMBERS= 1
 WANDER WILL HAVE PEAKED DISTRIBUTION.
 WHAT IS MAXIMUM ZONAL CHANNEL WANDER? 5
 106 SPARKS FIRED; OUTPUT TO PROFILE 1
 PREWANDER DATA IN PROFILE 13.

16

SUBROUTINE NUMBER=? E

VIII. Modification and Documentation of Additions

The pinwheel program structure and common data bank are intended to ease program revision and addition. Below various types of modifications are described, along with suggestions for documenting these changes.

A. Single function changes

An example will be given of a temporary change once made in the program. Not only will this serve to document that change but also to demonstrate how a small change can be made without perturbation of the "canned" version of the program.

It was desired to plot two sets of data on fixed scales; all "radial" data was to be plotted with an ordinate range 0-1000, and all "lateral" data with a range 0-0.9. It was decided that anything to be construed as lateral data would be plotted using profile 3 to contain the data, and all other profiles would be considered radial. The changes needed to do this are listed below:

```
8310 IF K3=3 Then Q6=0.9 else Q6=1000
8315 Q4=Q6
8320 Q3=Q5=0
```

Scaling is thus forced to be as intended, and the results may be seen in Figure 11, Anal. Chem. 48, 1519 (1976).

B. Changing profile labels

To change the name associated with a profile 1 through 19, the following steps may be taken:

- (1) In statements 57-66, the present profile name may be found, and the new name substituted for the old by retyping the entire line. Notice the word "profile" is not included in the profile name; the program supplies this as needed. Further, to obtain plots labeled "ring number" on the horizontal axis, one of the words "radial", "emission", or "epsilon" must appear in the profile name. Otherwise the horizontal axis label is "zone number".
- (2) The vertical axis label for each profile is found in line numbers 31-40. Again, to change a label, find the line containing that label and retype the whole line. Single quotes ('word') are needed only when the label contains a space.
- (3) A new documentation card should be punched for the table on page 0-2 of the program listing.
- (4) Note: Changing a profile label does not change any hardwired use of the profile. Check for hardwiring as needed.

C. Adding new profiles

Additional profiles must be added in numerically sequential order.

- (1) If a total of more than 25 profiles will result from the addition of new profiles, line 15 must be repunched with V redimensioned $V(n,50)$ where n is the total number of profiles.
- (2) In all cases, a title for the profile must be provided in a DATA statement (the first added profile's title could be placed in line 67) as must a label for the vertical plot axis (in line 41 et. seq.).
- (3) The total number of profiles must be given in line 1002:

1002 D2=n

where n is the total number of profiles for which titles and labels exist ($n=19$ at present).

- (4) A documentation card for the table on page 0-2 should be made. The format of a documentation card is:

C	column 1
*	column 5
information	columns 7-71
*	column 72

D. Changing subroutine default options and profiles

While it is possible to change the default options and profiles used by a subroutine during execution (by entering "-2"

in the core routine and then the new desired default as described above), a permanent change may be desired.

- (1) To change the default option, the list of defaults in lines 123 and 124 may be altered. For example, the present default option for subroutine 3 is option 2. To change this to option 4, line 123 would be repunched to read:

```
123 DATA 4,1,4,4,1,11,1
```

- (2) Default profiles are listed in statements 127 and 128, grouped by subroutine. That is, the order of listing is: Major profile, subroutine 1; Minor profile, subroutine 1; Major profile, subroutine 2;...; Minor profile, subroutine 8. Again, repunching the appropriate line changes the defaults.
- (3) Documentation may be updated by punching a new card for the table at the bottom of page 0-5.

E. General labels

Q\$(25) contains a potpourri of alphanumeric labels used by the program. At present 23 labels are used. To expand the list, be sure that either the total number of Q\$(n) entries is less than 26 or that Q\$(n) has been redimensioned. Then

- (1) Add the new alphanumerics, starting in line 107.

- (2) If n is the total number of Q(n) values, rewrite line 1003:$

1003 D3= n

F. Substitute subroutines

If a subroutine is written which is functionally different than any presently written, it should be assigned a new number and worked with as described in Section VIII.G below. However, if a routine is written which has a function similar to a previously existing routine, the substitute routine may be used interchangeably with the original routine subject to the following constraints:

- (1) It should occupy the same statement block as given at the bottom of page 0-1.
- (2) Default values as given in lines 123-124 and 127-128 should be corrected as appropriate.
- (3) The subroutine name should be changed, if appropriate, in lines 151-152.
- (4) A modified documentation card, if appropriate, should be punched for the table on page 0-5.
- (5) The "Gosub x" statement between lines 1940 and 2080 must transfer program control to an existent statement number.

- (6) A documentation block, as may be seen at the head of each subroutine, should be written (see for example, page 1-1).

G. Writing new subroutines

It is hoped that the procedure herein outlined is sufficiently flexible to allow a wide variety of new routines to be added, yet rigid enough that interchangeability among routines is possible. A procedure for writing subroutine 9 will be outlined, with additional comments to allow expansion to an indefinitely large number of routines.

- (1) Choose a name and subroutine number; the number must be sequential with those already in use. Let's dub subroutine 9 "Example".
- (2) Assign the routine a block of statements not given to any other routine. Let subroutine 9 occupy the block from 26000-28000.
- (3) The first few statements should be (in general)

```
26000 Rem Subroutine Example
26005 Gosub 15930
```

Statement 26005 will insure that

```
K1 = first ring or zone
K2 = last ring or zone
K3 = major profile
K4 = minor profile
K5 = option number
```

(4) The subroutine may now be written and a "documentation block" prepared describing the routine.

(5) Now the routine may be merged with the program.

(a) Insert a card in the table on page 0-1 reserving the appropriate statement block for the new subroutine.

(b) If the new subroutine is numbered higher than 10, see step 8 below.

(c) In line 124, enter the default option number.

(d) In line 128, enter the default major and minor profile numbers.

(e) In line 152, enter the new subroutine's name.
For the case of subroutine 9, line 152 would then read

152 DATA WANDER,EXAMPLE

(f) Repunch statement 1000 so that D1 is set equal to the number of subroutines. In this case, the result would be

1000 D1=9

(g) Add a documentation card to the table on page 0-5.

- (h) Append the "On K9..." statement in line 1935
to read

1935 On K9 Go to 1940,...,2080,2090

- (i) Add statements for subroutine linkage:

2090 Gosub 26005
2095 Go to 1500

- (j) At this point, the BASIC statements may be loaded
using a run (either batch or timesharing)
structured as follows:

```
@RUN AS,2231,1893602639,$10.00
@PASS word
@BASIC CHEMISTRY*WALTERS//01.
OLD:ABEL3
      (new and modified cards)
REPLACE
BYE
@FIN
```

- (6) Cost saving thoughts:

- (a) When loading new routines, have statements in
numerically ascending order.
- (b) Several service routines appear on page 0-10.
They may be used to save core space, as they are
already employed throughout the program.

- (7) Essential point: NEVER resequence ABEL3. First of
all, by leaving the sequence as given, line numbers
have functional significance (9000's are all PEPSUB

statements, for example). Also for a program this large, resequencing is immensely expensive and may result in IGDM (i.e. program wipeout) errors.

(8) If over ten routines are to be used, several additional steps are needed for expansion. These are:

(a) Variables C(n), D(n), F(n), G(n,2), H(n,2), L(n,2), and CS(n) must all be redimensioned with $n > 10$.

(b) Due to an inability to use continuation lines in BASIC, a second ON variable GO TO statement must be melded in. A plausible method is:

```

1933 IF K9 >10 Then 2150
      :
2150 K7=K9-10
2160 On K7 Go to 2170,2180,...
2170 GOSUB 30005
2175 Go to 1500
      :

```

Otherwise, additions would be the same.

Appendix A-1

VARIABLE LIST

0 = Core or initialization routines.

Variable	Applicable Subroutines	Usage
A1	0,2,5	Zone width in centimeters
A2	0,5	1/A1
A(50,50)	0,2,5	Abel Area Matrix
B(50,50)	0,5	Inverse Abel Matrix
C(10)	0	Default option array
C\$(10)	0	Array containing subroutine names
D1	0	Number of subroutines
D2	0	Number of labeled profiles
D3	0	Number of entries in the Q\$(n) array
D(10)	0,2	Array containing options to be fed to called routine(s)
E(6)	0	Array for input core routine commands
E\$(6)	0	Labels for soliciting core routine commands
F(10)	0-6	Flags--see listing page 0-2 for details

Variable	Applicable Subroutines	Usage
G(10,2)	0	Array containing default profile information
H(10,2)	0,2	Array containing profile information to be fed to called routine
I	All	Loop index
IS	0,4,5	Scratch alphanumeric variable
IS(2)	0	Batch/timesharing control and labeling
J	0,2,5	Loop index
J1	0	Dummy used to read in A and B arrays
K1	All but 2	First (inner) ring or zone limit
K2	All but 2	Last (outer) ring or zone limit
K3	All but 2	Major profile number
K4	All but 2	Minor profile number
K4	1	Used in directing program flow in options 5-10
K5	All	Option number
K6	4	Number of zones profile is to be shifted
	5	Auxiliary used to keep track of profile numbers
	7	Number of points to be smoothed
	8	Same as in subroutine 4

Variable	Applicable Subroutines	Usage
K7	4	Profile into which unshifted profile is to be stored
	5	Output profile number
	8	Same as subroutine 4
K8	0	Input and array control
	5	Auxiliary ring number register
K9	0	Subroutine number being called
	5	Auxiliary ring number register
L(10,2)	0,2	Ring and zone information to be passed to called subroutines
M1	A11	Last emission ring number; ≥ 0
M2	A11	First absorption ring number $M2 = M1 + 1, \leq 51$
M\$(25)	0,1,6	Description of profile ordinate
N1	2	First ring and zone number
	3	Power upon which noise depends
	4	Auxiliary ring or zone number in shift process
N2	2	Last ring and zone number
	4	Auxiliary ring or zone number in shift process
N3	2	Auxiliary ring and zone control
	4	Option control in slave shifting routine

Variable	Applicable Subroutines	Usage
N4	2	Auxiliary ring and zone control
	4	Auxiliary ring or zone number in shift process
N5	2	Option number
	4	Auxiliary ring or zone number in shift process
N6	2	Major profile number
N7	2	Minor profile number
NS(25)	0,1,2,3,6	Profile name array
P1	8	Total number of discharges to be used in modeling wander
P2	8	Maximum number of zones central discharge axis may wander
P3	8	Amount of wander for an individual discharge; for centrally peaked wander, auxiliary for scaling the number of discharges having a particular degree of wander
P4	8	Counter for number of discharges used in modeling
P5	8	Option number
P6	8	Major profile
P9	8	Scaling parameter for centrally peaked wander
Q	0	Scratch variable
Q1	1-4	Scratch variable
Q2	0,1,5,6	Scratch variable

Variable	Applicable Subroutines	Usage
Q3	0,1	Scratch variable
Q3-Q8	6	Plot scaling computation and control
Q\$	0,6	Input scratch pad
Q1\$	6	Plot option control
Q\$(25)	0,1,6	Assorted alphanumeric information
S	3	Maximum profile data value
S\$	6	Plot scaling control
T	3	Noise scaling variable
T\$	0,1,3,4,6	Input scratch variable
V(25,50)	All	Data profiles--main data bank
X,Y, and Z variables	0,6	See PEPSUB and MINILOT documentation; variable meanings are identical

Appendix A-2**PROGRAM LISTING**

The number before the dash at the top of each page refers to the subroutine number. "0" is the core/initialization routine.

0-1

```

1 C *****
2 C *
3 C * PROGRAM ABEL3 WRITTEN IN BASIC
4 C * DOCUMENTED FOR PROGRAM VERSION OF JULY, 1977.
5 C *
6 C * PROGRAM ALLOWS MODELING OF THE OBSERVATION OF AN EMITTING OR
7 C * ABSORBING DISCHARGE WITH CYLINDRICAL SYMMETRY. INCLUDED
8 C * PHENOMENA ARE: EMISSION, ABSORPTION WHICH IS SPATIALLY
9 C * FARTHER FROM THE SPARK AXIS THAN THE EMISSION, EMITTING
10 C * CONTINUUM BACKGROUND, SPARK WANDER, NOISE IN THE SIGNAL, AND
11 C * SMOOTHING OF THE SIGNAL. THE PROGRAM IS SO STRUCTURED AS TO
12 C * ALLOW ANYONE FAMILIAR WITH BASIC TO ADD HIS OWN IDEAS TO THOSE
13 C * ALREADY PROGRAMMED.
14 C *
15 C * PREPARED BY A. SCHEELINE UNDER THE DIRECTION OF:
16 C * PROF. JOHN P. WALTERS
17 C * DEPARTMENT OF CHEMISTRY
18 C * UNIVERSITY OF WISCONSIN
19 C * MADISON, WISCONSIN 53706
20 C *
21 C *****
22 C *****
23 C *
24 C * LINE NUMBER ASSIGNMENTS IN PROGRAM ABEL3
25 C * 0- 1000 DATA AND DIM STATEMENTS.
26 C * 1000- 1499 FIRST PASS INITIALIZATION.
27 C * 1500- 3000 PINWHEEL HUB; MAIN CONTROL ROUTINE.
28 C * 3000- 3500 GENERAL REINITIALIZATION ROUTINE.
29 C * 4000- 5000 SUBROUTINE CONSTRUCT
30 C * 6000- 7000 SUBROUTINE FORWARD
31 C * 8000- 8900 SUBROUTINE PRINT-PLOT
32 C * 9000- 9999 PEPSUB (MODIFIED BY HARDWIRING OPTIONS).
33 C * 10000-10999 MINI-PLOT (MODIFIED BY HARDWIRING OPTIONS).
34 C * 11000-11500 EXECUTION TERMINATION ROUTINE.
35 C * 12000-13000 SUBROUTINE NOISE
36 C * 14000-15000 SUBROUTINE SHIFT
37 C * 15900-15920 PRINT PROFILE RELATED INFORMATION--SLAVE ROUTINE.
38 C * 15930-15940 INTERCONNECT CORE AND SUBROUTINES--SLAVE ROUTINE.
39 C * 16000-17000 SUBROUTINE ABEL
40 C * 18000-19000 SUBROUTINE SMOOTH
41 C * 22000-22100 SLAVE ERROR HANDLING ROUTINES.
42 C * 24000-25000 SUBROUTINE WANDER
43 C * -99999 END STATEMENT.
44 C *
45 C * ALL OTHER STATEMENT NUMBERS ARE AVAILABLE FOR
46 C * NEW AND DIFFERENT SUBROUTINES.
47 C *
48 C *****

```

0-2

```

49 C *****
50 C *
51 C * TABLE CORRELATING PROFILE NUMBERS AND MEANINGS:
52 C * 1) USER CONSTRUCTED RADIAL EMISSION PROFILE.
53 C * 2) USER CONSTRUCTED RADIAL ABSORPTION PROFILE.
54 C * 3) LATERAL INTENSITY PROFILE.
55 C * 4) BACKLIGHT PROFILE.
56 C * 5) CONSTRUC SCRATCH REGISTER.
57 C * 6) EMISSION/ABSORPTION PROFILE CORRESPONDING TO 3) AND 4).
58 C * ASSUMES DREAMS MODEL.
59 C * 7) EMISSION PROFILE BASED ON EMISSION MODEL ONLY.
60 C * 8) USER CONSTRUCTED EMISSION/ABSORPTION RADIAL PROFILE.
61 C * 9) NOISE SCRATCH REGISTER.
62 C * 10) BACKGROUND INTENSITY DISTRIBUTION.
63 C * 11) BACKGROUND SPECIES DISTRIBUTION.
64 C * 12) SMOOTH SCRATCH REGISTER.
65 C * 13) SHIFT SCRATCH REGISTER (LATERAL INTENSITY PROFILE).
66 C * 14) SHIFT SCRATCH REGISTER (BACKGROUND INTENSITY PROFILE).
67 C * 15) ABSORPTION COMPENSATED INTENSITY PROFILE.
68 C * 16) WANDER SCRATCH REGISTER.
69 C * 17) WANDER ACCUMULATOR PROFILE.
70 C * 18) SCRATCH REGISTER A.
71 C * 19) SCRATCH REGISTER B.
72 C *
73 C *****
74 C *****
75 C *
76 C * TABLE OF FLAG MEANINGS
77 C * 1) LAST EMISSION ZONE NUMBER AS SET IN INITIALIZATION.
78 C * 2) ABSORPTION OR EMISSION PROFILE CONSTRUCTED--1=YES, 0=NO.
79 C * 3) BACKLIGHT PROFILE CONSTRUCTED--1=YES, 0=NO.
80 C * 4) TRANSMITTED INTENSITY CALCULATED SINCE BACKLIGHT PROFILE
81 C * CONSTRUCTED--1=NO, 0=YES.
82 C * 5) IF 4=NO, IS IT STILL OK TO DO THE INVERSION--1=YES, 0=NO.
83 C * 7) PLOT ENABLE FLAG--1=PLOT, 0=AWAIT NEXT PASS.
84 C * 8) SHOULD CONSTRUC AUTOMATICALLY CREATE V(8,I) FROM V(1,I) AND
85 C * V(2,I)--1=NO, 0=YES.
86 C * 9) BATCH VS. TIMESHARE MODE. 1=BATCH, 0=TIMESHARE.
87 C * 6) AND 10) ARE CURRENTLY UNASSIGNED.
88 C *
89 C *****

```

0-3

```

90 C *****
91 C *
92 C * STARTUP SEQUENCE; DATA FOR DEFAULTS, MATRICES, AND LABELS.
93 C *
94 C *****
95 10 DIM A(50,50),B(50,50),C(10),D(10),E(6),F(10),G(10,2),H(10,2),I(2)
96 15 DIM L(10,2),M(25),N(25),O(25),U(25,50),E(6),C(10)
97 17 DIM X(55),Y(55)
98 20 VAR=ZERO
99 30 REM N# VALUES
100 31 DATA 'RELATIVE EMISSION VALUE','EPSILON.CONCENTRATION
101 32 DATA 'OBSERVED INTENSITY','NON-ABSORBED VALUE','CONTAINED VALUE'
102 33 DATA 'EMISSION/EPSILON.CONC.'
103 34 DATA 'RELATIVE EMISSION VALUE'
104 35 DATA 'EMISSION/EPSILON.CONC.','CONTAINED VALUE'
105 36 DATA 'RELATIVE INTENSITY VALUE','RELATIVE EMISSION VALUE'
106 37 DATA 'CONTAINED VALUE','CONTAINED VALUE','CONTAINED VALUE'
107 38 DATA 'ABSORPTION COMP. INTENSITY'
108 39 DATA 'CONTAINED VALUE','CONTAINED VALUE'
109 40 DATA 'CONTAINED VALUE','CONTAINED VALUE'
110 41 REM 41 TO 55 RESERVED FOR MORE N# VALUES.
111 56 REM N# VALUES.
112 57 DATA 'U.C. RADIAL EMISSION','U.C. RADIAL ABSORPTION'
113 58 DATA 'LATERAL INTENSITY','U.C. BACKLIGHT'
114 59 DATA 'SCRATCH REGISTER','COMPUTED EMISSION/ABSORPTION'
115 60 DATA 'ABSORPTION UNCOMPENSATED CALCULATED EMISSION'
116 61 DATA 'U.C. EMISSION/ABSORPTION','NOISE SCRATCH REGISTER'
117 62 DATA 'BACKGROUND INTENSITY','BACKGROUND RADIAL EMISSION'
118 63 DATA 'SMOOTH SCRATCH REGISTER','SHIFT SCRATCH REGISTER 1'
119 64 DATA 'SHIFT SCRATCH REGISTER 2','ABEL SCRATCH REGISTER'
120 65 DATA 'WANDER SCRATCH REGISTER','WANDER ACCUMULATOR'
121 66 DATA 'SCRATCH REGISTER A','SCRATCH REGISTER B'
122 67 REM 67 TO 99 RESERVED FOR MORE N# VALUES.
123 100 REM Q# VALUES
124 101 DATA 'ON-AXIS GAUSSIAN','OFF-AXIS GAUSSIAN','ELLIPSOIDAL'
125 102 DATA 'HOMOGENEOUS','INPUT','SCALE','ADD TO'
126 103 DATA 'ALL POSSIBLE','SELECTED','POSITIVE','NEGATIVE'
127 104 DATA 'PROFILE','RINGS','ZONES','RING NUMBER','ZONE NUMBER'
128 105 DATA E,R,S,T,D
129 106 DATA 'MAJOR','SECONDARY'
130 107 REM 107-120 RESERVED FOR MORE Q# VALUES. CHECK DIMENSION.
131 121 REM VALUES FOR C
132 123 DATA 4,1,2,4,1,11,1
133 124 DATA 1
134 125 REM VALUES FOR G
135 127 DATA 1,11,8,2,3,9,3,10,3,4,4,1,3,12
136 128 DATA 3,16
137 130 REM LABLES FOR INPUT(E(6))
138 131 DATA 'SUBROUTINE NUMBER=','WHICH OPTION'
139 132 DATA 'MAJOR PROFILE INVOLVED=','SECONDARY PROFILE INVOLVED='
140 133 DATA 'FIRST ZONE OR RING NUMBER='
141 134 DATA 'LAST (OUTER) ZONE OR RING NUMBER='
142 150 REM C# VALUES
143 151 DATA CONSTRUC,FORWARD,NOISE,SHIFT,ABEL,PRINT-PLOT,SMOOTH
144 152 DATA WANDER
145 1000 D1=8
146 1002 D2=19

```

0-4

```

147      1003 D3=23
148      1004 EXEC 'BASG-A ABEL*DATA. . '
149      1006 EXEC 'BUSE FILE.,ABEL*DATA. . '
150      1008 OPEN FILE FOR SYMBOLIC INPUT,3
151      1009 REM AREA MATRIX FIRST, THEN INVERSE MATRIX.
152      1010 FOR I=1 TO 50
153      1015 FOR J=1 TO 10
154      1020 J1=5+J
155      1025 INPUT FROM 3: A(I,J1-4),A(I,J1-3),A(I,J1-2),A(I,J1-1),A(I,J1)
156      1030 NEXT J
157      1035 NEXT I
158      1040 FOR I=1 TO 50
159      1045 FOR J=1 TO 10
160      1050 J1=5+J
161      1055 INPUT FROM 3: B(I,J1-4),B(I,J1-3),B(I,J1-2),B(I,J1-1),B(I,J1)
162      1060 NEXT J
163      1065 NEXT I
164      1068 CLOSE 3
165      1070 MAT READ M$(D2)
166      1073 MAT READ N$(D2)
167      1076 MAT READ O$(D3)
168      1079 MAT READ C(D1)
169      1082 MAT READ G(D1,2)
170      1085 MAT READ E$
171      1088 MAT READ C$(D1)
172      1090 PRINT 'BATCH OR TIMESHARE RUN: INPUT "BATCH" OR';
173      1095 PRINT ' "TIME" OR JOB ABORTS'
174      1100 INPUT I$(2)
175      1105 IF I$(2)='TIME' THEN GO TO 1300
176      1110 IF I$(2)='BATCH' THEN GO TO 1115 ELSE GO TO 1140
177      1115 F(9)=1
178      1120 'BATCH RUN ACTIVE.'
179      1125 'RUN IDENTIFIER INPUT';
180      1130 INPUT I$(2)
181      1135 GO TO 1300
182      1140 'ILLEGAL RUN TYPE. JOB ABANDON.'
183      1145 STOP
184      1300 PRINT 'DO YOU WISH TO RANDOMIZE? "1" OR "YES" OR "Y"';
185      1305 ' IS AFFIRMATIVE.'
186      1310 'ALL OTHER RESPONSES ARE NEGATIVE.';
187      1315 INPUT I$(1)
188      1320 IF I$(1)='1' OR I$(1)='YES' OR I$(1)='Y' THEN 1325 ELSE 1330
189      1325 RANDOMIZE
190      1330 PRINT 'HOW MANY RANDOM NUMBERS DO YOU WANT TO SKIP?';
191      1335 INPUT E(1)
192      1340 E(1)=INT(E(1))
193      1345 IF E(1)<0 THEN E(1)=0
194      1350 IF E(1)=0 THEN 1360
195      1355 FOR I=1 TO E(1) G1=RND
196      1360 GO SUB 3040
197      1365 GO TO 1500
198      1370 REM END OF INITIALIZATION

```


0-5

```

199 C *****
200 C *
201 C * CONTROL ROUTINE SPECIFIES:
202 C *
203 C * 1) SUBROUTINE NUMBER.
204 C * 2) OPTION NUMBER WITHIN SUBROUTINE.
205 C * 3) MAJOR PROFILE AFFECTED.
206 C * 4) MINOR PROFILE AFFECTED.
207 C * 5) FIRST (INNER) ZONE OR RING AFFECTED.
208 C * 6) LAST (OUTER) ZONE OR RING AFFECTED.
209 C *
210 C * IN BATCH MODE, THESE ARE SPECIFIED AS 6 NUMBERS SEPARATED BY
211 C * COMMAS ON A SINGLE INPUT CARD. INTERACTIVELY, VALUES ARE
212 C * SUPPLIED IN RESPONSE TO A PROMPT. IN ADDITION, NONNUMERIC
213 C * VALUES WHICH MAY BE GIVEN IN CONJUNCTION WITH NUMERIC COMMANDS
214 C * ARE AS FOLLOWS:
215 C *
216 C * E ERROR-REASK QUESTION.
217 C * R RESTART CONTROL CALLING SEQUENCE; THROW OUT
218 C * CURRENT CONTROL VALUES.
219 C * S SHUT DOWN PROGRAM, SAVING APPROPRIATE OUTPUT FILES.
220 C * USE IN PLACE OF THE BASIC 'STOP' COMMAND.
221 C * USE OF 'STOP' WILL WIPE OUT PLOT INFORMATION AND
222 C * LEAVE YOU IN BASIC. IF NO PLOTS ARE GENERATED,
223 C * S LEAVES YOU IN BASIC ANYWAY. ALSO, IN BATCH MODE,
224 C * S LEAVES YOU IN BASIC.
225 C * T IDENTICAL IN USE TO S. S STANDS FOR STOP, T
226 C * STANDS FOR TERMINATE. USE EITHER OR BOTH.
227 C * D ON ALL SUBSEQUENT QUESTIONS REGARDING THIS
228 C * SUBROUTINE CALL, USE DEFAULT VALUES RATHER THAN
229 C * ASKING FOR INPUT.
230 C *
231 C * ALL OF THE ABOVE ALPHABETIC COMMANDS MAY BE USED ALONE EXCEPT D
232 C * WHICH MUST BE PRECEDED BY A NUMBER. SINCE 0 IS A UNIVERSAL
233 C * DEFAULT VALUE, ENTERING 0D WILL GIVE DEFAULT VALUES NOT ONLY
234 C * ON SUBSEQUENT QUESTIONS BUT ON THE CURRENT QUESTION AS WELL.
235 C * THE LETTERS ARE SEARCHED FOR AND HAVE EFFECT IN THE ORDER SHOWN.
236 C *
237 C *****
238 C *****
239 C *
240 C * SUBROUTINES AND DEFAULT VALUES ARE:
241 C *
242 C * SUBROUTINE DEFAULT VALUES
243 C * NAME NUMBER OPTION MAJOR PROFILE MINOR PROFILE
244 C * CONSTRU 1 4 1 11
245 C * FORWARD 2 1 8 2
246 C * NOISE 3 2 3 9
247 C * SHIFT 4 4 3 10
248 C * ABEL 5 1 3 4
249 C * PRINT-PLOT 6 11 6 1
250 C * SMOOTH 7 1 3 12
251 C * WANDER 8 1 3 16
252 C *
253 C * LEGAL ANSWERS TO 'WHICH OPTION' AND WHAT THEY MEAN.
254 C * POSITIVE INTEGERS VALUE DIRECTLY ASSIGNED AS OPTION FOR
255 C * THIS CALL TO THIS SUBROUTINE.

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0-6

```

236 C * 0 USE DEFAULT OPTION. *
237 C * -1 LEAVE OPTION UNCHANGED FROM PREVIOUS CALL *
238 C * TO THIS SUBROUTINE. THIS CHOICE IS RIFE *
239 C * WITH OPPORTUNITIES FOR ERRORS; ITS USE *
240 C * IS NOT RECOMMENDED. *
241 C * -2 CHANGE THE DEFAULT OPTION FOR THIS *
242 C * SUBROUTINE; THE NEW DEFAULT OPTION IS *
243 C * IN EFFECT IF THE SUBROUTINE IS IN FACT *
244 C * ALLOWED TO EXECUTE DURING THIS CALL. *
245 C * *
246 C * LEGAL VALUES FOR PROFILE NUMBERS AND WHAT THEY MEAN. *
247 C * INSTRUCTIONS HERE ARE THE SAME AS IN THE SECTION JUST CONCLUDED *
248 C * ON ASSIGNING OPTION VALUES, EXCEPT THAT THE WORDS 'PROFILE *
249 C * NUMBER' SHOULD BE SUBSTITUTED FOR THE WORD 'OPTION' ABOVE. *
250 C * *
251 C * LEGAL RING AND ZONE NUMBER ASSIGNMENTS. *
252 C * POSITIVE INTEGERS VALUES BETWEEN 1 AND 50 ARE USED TO *
253 C * INDICATE LIMITS DIRECTLY. DEFAULT *
254 C * ASSIGNMENT OVERRIDES DIRECT ASSIGNMENT. *
255 C * 0 ALL ZONES AND RINGS 1 THROUGH 50 ARE *
256 C * OPERATED ON BY THE SUBROUTINE. *
257 C * -1 ONLY ZONES OR RINGS IN THE EMISSION REGION *
258 C * ARE OPERATED ON BY THE SUBROUTINE. *
259 C * -2 ONLY RINGS AND ZONES IN THE ABSORPTION *
260 C * REGION ARE OPERATED ON BY THE SUBROUTINE. *
261 C * *
262 C *****
263 1499 REM MAIN CONTROL ROUTINE
264 1500 FOR I=1 TO 6
265 1503 IF I=1 THEN PRINT ' '
266 1505 IF I=1 AND F(9)=1 THEN 1750 ELSE IF F(9)=1 THEN 1605
267 1510 PRINT E$(I);
268 1515 INPUT T$
269 1520 T$=Q$(17)
270 1522 IF CNT(I$,T$)>0 THEN 1510
271 1525 T$=Q$(18)
272 1527 IF CNT(I$,T$)>0 THEN 1530 ELSE 1540
273 1530 I=0
274 1535 GO TO 1915
275 1540 T$=Q$(19)
276 1541 Q$=Q$(20)
277 1542 IF CNT(I$,T$)>0 OR CNT(I$,Q$)>0 THEN 11001
278 1545 Q2=LEN(I$)
279 1548 IF Q2>5 THEN 1510
280 1550 FOR J=1 TO Q2
281 1555 Q=GET(I$,J)
282 1560 IF Q<48 OR Q>57 THEN IF Q<>9 AND Q<>33 AND Q<>34 THEN 1510
283 1565 NEXT J
284 1570 T$=Q$(21)
285 1573 Q3=SEP(I$,T$,1)
286 1575 IF Q3>0 THEN 1590
287 1580 E(I)=VAL(I$)
288 1585 GO TO 1605
289 1590 Q=Q3-1
290 1592 T$=Q$(21)
291 1594 IF Q=0 OR CNT(I$,T$)>1 THEN 1510
292 1595 LET I$(1)=PAD$(I$,Q)

```

0-7

```

313 1600 E(I)=VAL(I*(1))
314 1605 ON I GO TO 1610,1640,1680,1740,1760,1845
315 1610 IF E(I)<1 OR E(I)>D1 THEN 1620 ELSE 1630
316 1620 'ILLEGAL SUBROUTINE NUMBER. TRY AGAIN.'
317 1625 IF F(9) =1 THEN 1750 ELSE 1510
318 1630 K9=E(I)
319 1635 GO TO 1880
320 1640 IF E(I)>0 THEN D(K9)=E(I)
321 1645 IF E(I)=0 THEN D(K9)=C(K9)
322 1650 IF E(I)=-2 THEN 1660
323 1655 GO TO 1880
324 1660 PRINT 'NEW DEFAULT OPTION FOR 'IC*(K9)
325 1665 INPUT C(K9)
326 1670 E(I)=0
327 1675 GO TO 1645
328 1680 K8=1
329 1685 IF E(I)>D2 THEN 1690 ELSE 1700
330 1690 PRINT 'PROFILE NUMBER 'E(I) IS ILLEGAL. TRY AGAIN.'
331 1695 GO TO 1510
332 1700 IF E(I)>0 THEN H(K9,K8)=E(I)
333 1705 IF E(I)=0 THEN H(K9,K8)=G(K9,K8)
334 1710 IF E(I)=-2 THEN 1720
335 1715 GO TO 1880
336 1720 PRINT 'NEW DEFAULT 'IG*(21+K8) PROFILE NUMBER FOR '
337 1722 PRINT 'SUBROUTINE 'IC*(K9)
338 1725 INPUT G(K9,K8)
339 1730 E(I)=0
340 1735 GO TO 1705
341 1740 K8=2
342 1745 GO TO 1685
343 1750 INPUT E(1),E(2),E(3),E(4),E(5),E(6)
344 1755 IF E(1) <=0 THEN 11001 ELSE 1605
345 1760 K8=1
346 1765 IF E(I)=0 THEN 1790
347 1770 IF E(I)=-1 THEN 1805
348 1775 IF E(I)=-2 THEN 1825
349 1780 IF E(I)>0 AND E(I)<=50 THEN L(K9,K8)=E(I) ELSE 1787
350 1783 IF K8=2 AND L(K9,1)>L(K9,2) THEN 1900
351 1785 GO TO 1880
352 1787 PRINT 'RING OR ZONE NUMBER 'E(I) IS ILLEGAL. TRY AGAIN.'
353 1788 GO TO 1510
354 1790 L(K9,1)=1
355 1795 L(K9,2)=50
356 1800 GO TO 1920
357 1805 IF M1=0 THEN 1855
358 1810 L(K9,1)=1
359 1815 L(K9,2)=M1
360 1820 GO TO 1920
361 1825 IF M2=51 THEN 1870
362 1830 L(K9,1)=M2
363 1835 L(K9,2)=50
364 1840 GO TO 1920
365 1845 K8=2
366 1850 GO TO 1765
367 1855 'YOU CAN'T USE THE EMISSION REGION; THERE ISN'T ANY.'
368 1860 I=5
369 1865 GO TO 1510

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0-8

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370 1870 'YOU CAN'T USE THE ABSORPTION REGION; THERE ISN'T ANY.'
371 1875 GO TO 1860
372 1880 IF F(9)=1 OR Q3=0 OR I=6 THEN 1915
373 1885 I=I+1
374 1890 FOR J=I TO 6 E(J)=0
375 1895 GO TO 1605
376 1900 'IMPROPER RING OR ZONE NUMBER COMBINATION.'
377 1905 I=5
378 1910 GO TO 1510
379 1915 NEXT I
380 1920 PRINT
381 1925 PRINT 'IN SUBROUTINE 'FC$(K9)'; OPTION 'ID(K9)'; WILL BE'
382 1930 PRINT 'PERFORMED ON RINGS OR ZONES 'L(K9,1)'; TO 'L(K9,2)'
383 1932 PRINT 'PROFILE NUMBERS='H(K9,1);H(K9,2)'
384 1935 ON K9 GO TO 1940,1960,1980,2000,2020,2040,2060,2080
385 1940 GO SUB 4000
386 1945 GO TO 1500
387 1960 GOSUB 6005
388 1965 GO TO 1500
389 1980 GOSUB 12005
390 1985 GO TO 1500
391 2000 GOSUB 14010
392 2005 GO TO 1500
393 2020 GOSUB 16010
394 2025 GO TO 1500
395 2040 GO SUB 8001
396 2045 GO TO 1500
397 2060 GOSUB 18005
398 2065 GO TO 1500
399 2080 GOSUB 24105
400 2085 GO TO 1500
```

0-9

```

401 C *****
402 C *
403 C * REINITIALIZATION ROUTINE.
404 C *
405 C *****
406 3000 REM REINITIALIZATION ROUTINE
407 3001 FOR I=1 TO 6 F(I)=0
408 3005 F(8)=0
409 3010 FOR I=1 TO D2
410 3015 FOR J=1 TO 50
411 3020 U(I,J)=0
412 3025 NEXT J
413 3030 NEXT I
414 3035 FOR I=1 TO 10 D(I)=H(I,1)=H(I,2)=0
415 3040 PRINT 'WHAT IS SPATIAL ZONE SIZE IN MICRONS';
416 3045 INPUT A1
417 3050 IF A1<=0 THEN 3040
418 3055 A1=A1*1.E-4
419 3060 A2=1/A1
420 3065 PRINT 'WHAT IS LAST EMISSION RING';
421 3070 INPUT F(1)
422 3075 F(1)=INT(F(1))
423 3080 IF F(1)<0 THEN F(1)=0
424 3085 IF F(1)>50 THEN F(1)=50
425 3090 M1=F(1)
426 3095 M2=F(1)+1
427 3100 'SHOULD THE TRANSMITTANCE PROFILE PROTECTION FLAG BE ON--'
428 3105 'RECOMMENDED THAT IT BE ON.'
429 3110 'ENTER 'ON' OR 'OFF'';
430 3115 PRINT 'YOUR CHOICE';
431 3120 INPUT I$(1)
432 3125 IF I$(1)='OFF' THEN F(5)=1
433 3127 IF I$(1)='-2' OR I$(1)='0' OR I$(1)='ON' THEN F(5)=0 ELSE F(5)=1
434 3128 IF I$(1)<>'OFF' THEN IF F(5)=1 THEN 3100
435 3130 PRINT 'SHOULD PROFILE 8 BE AUTOMATICALLY CONSTRUCTED';
436 3140 INPUT I$(1)
437 3145 IF I$(1)='YES' OR I$(1)='Y' OR I$(1)='0' OR I$(1)='-2' THEN F(8)=0 ELSE F(8)=1
438 3150 RETURN
439 3155 REM END OF REINITIALIZATION ROUTINE.

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0-10

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440 C *****
441 C *
442 C * RUN TERMINATION ROUTINE. CALLED ON T OR S SPECIFICATION *
443 C * IN CONTROL ROUTINE. *
444 C *
445 C *****
446 11001 IF F(9)=1 THEN Z$='CLOSE' ELSE Z$='DONE'
447 11005 Z9=0
448 11025 IF Z1>0 THEN 11030 ELSE 11035
449 11030 GOSUB 9124
450 11035 GO TO 99999
451 C *****
452 C *
453 C * SERVICE LABEL PRINTING ROUTINE. *
454 C *
455 C *****
456 15900 PRINT 'PROFILE 'K3;', THE 'N$(K3);' PROFILE'
457 15905 RETURN
458 22020PRINT'IN 'C$(K9);', RINGS OR ZONES 'K1;' TO 'K2;' ARE AFFECTED.'
459 22025 RETURN
460 C *****
461 C *
462 C * SERVICE ROUTINE: INTERCONNECTION OF CORE AND SUBROUTINES. *
463 C *
464 C *****
465 15930 K1=L(K9,1)
466 15935 K2=L(K9,2)
467 15940 K3=H(K9,1)
468 15945 K4=H(K9,2)
469 15950 K5=D(K9)
470 15955 RETURN
471 C *****
472 C *
473 C * ERROR HANDLING ROUTINE. *
474 C *
475 C *****
476 22000 PRINT 'OPTION 'K5;' IS ILLEGAL IN SUBROUTINE 'C$(K9);'.'
477 22005 PRINT 'RETURN AND TRY AGAIN.'
478 22010 RETURN

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0-11

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479 C *****
480 C *
481 C * DUMMY STATEMENTS SUBSTITUTING FOR UNLOADED SUBROUTINES. *
482 C * *
483 C *****
484 4000 PRINT 'CONSTRUC NOT LOADED. INSERT IF DESIRED.'
485 4025 RETURN
486 6005 PRINT 'FORWARD NOT LOADED. INSERT IF DESIRED.'
487 6010 RETURN
488 8001 PRINT 'OUTPUT ROUTINE ABSENT. LOAD IF DESIRED.'
489 8010 RETURN
490 9018 PRINT 'PEPSUB OMITTED. LOAD IF DESIRED.'
491 9020 RETURN
492 9126 GO TO 9018
493 10009 PRINT 'MINIPLT OMITTED. LOAD IF DESIRED.'
494 10012 RETURN
495 12005 PRINT 'NOISE ROUTINE NOT LOADED. INSERT IF DESIRED.'
496 12010 RETURN
497 14010 PRINT 'SHIFT ROUTINE ABSENT. LOAD IF DESIRED.'
498 14035 RETURN
499 14205 PRINT 'SHIFT ROUTINE NEEDED FOR WANDER OMITTED.'
500 14210 PRINT 'ALLOW TO LOOP UNTIL DONE.'
501 14215 RETURN
502 16010 PRINT 'SUBROUTINE ABEL ABSENT. LOAD IF DESIRED.'
503 16035 RETURN
504 18005 PRINT 'SMOOTH ROUTINE ABSENT. LOAD IF DESIRED.'
505 18029 RETURN
506 24105 PRINT 'SUBROUTINE WANDER OMITTED. LOAD IF DESIRED.'
507 24110 RETURN
508 99999 END
509 C *****
510 C *
511 C * END OF CORE ROUTINES. *
512 C * *
513 C *****

```

1-1

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1 C *****
2 C *
3 C * SUBROUTINE CONSTRUC
4 C *
5 C * OPTIONS ARE
6 C * 1) ADD ON-AXIS GAUSSIAN PROFILE TO PRESENT PROFILE.
7 C * 2) ADD OFF-AXIS GAUSSIAN PROFILE TO PRESENT PROFILE.
8 C * 3) ADD ELLIPSOIDAL PROFILE TO PRESENT PROFILE.
9 C * 4) ADD HOMOGENEOUS (CONSTANT IN EACH RING OR ZONE) PROFILE
10 C * TO PRESENT PROFILE.
11 C * 5) INPUT DIRECTLY VALUES IN A FEW ZONES OR RINGS.
12 C * 6) INPUT DIRECTLY VALUES FOR ALL POSSIBLE (BASED ON LOOP
13 C * INDICES CHOSEN) ZONES OR RINGS.
14 C * 7) SCALE THE VALUES IN A FEW ZONES OR RINGS.
15 C * 8) SCALE ALL POSSIBLE ZONES OR RINGS.
16 C * 9) ADD INPUT VALUES TO THE PRESENT VALUE OF A FEW ZONES OR RINGS*
17 C * 10) ADD INPUT VALUE TO PRESENT PROFILE VALUE IN ALL POSSIBLE
18 C * RINGS OR ZONES.
19 C * 11) ADD MINOR PROFILE TO MAJOR PROFILE; STORE IN MAJOR PROFILE.
20 C * 12) SUBTRACT MINOR PROFILE FROM MAJOR PROFILE; STORE IN MAJOR
21 C * PROFILE.
22 C * 13) SCALE ALL VALUES BY AN INPUT CONSTANT.
23 C * 14) CROSS-MULTIPLY THE INPUT PROFILES; STORE IN MAJOR PROFILE.
24 C * BY ADDING 20 TO ANY OF THE ABOVE OPTIONS, THE OPTION
25 C * WILL BE EXECUTED AFTER THE APPLICABLE SECTION OF THE PROFILE
26 C * HAS BEEN CLEARED.
27 C * PERMANENT SCRATCH REGISTER FOR THIS ROUTINE IS V(5,I).
28 C *
29 C *****
30 3999 REM SUBROUTINE CONSTRUC
31 4000 GOSUB 15930
32 4025 IF K5>34 THEN 4070 ELSE IF K5>14 AND K5<20 THEN 4070
33 4030 IF K3=1 OR K3=2 THEN F(2)=1
34 4035 IF K3=4 THEN 4080
35 4040 IF K5<20 THEN 4100
36 4045 PRINT Q$(12);' 'K3';' THE 'N$(K3);' 'Q$(12);' IS BEING CLEARED'
37 4050 'FROM ZONE OR RING NUMBER 'K1' TO ZONE OR RING NUMBER 'K2';'
38 4055 FOR I=K1 TO K2 V(K3,I)=0
39 4060 K5=K5-20
40 4065 IF K5<=0 THEN 4100 ELSE RETURN
41 4070 GO TO 22000
42 4080 F(3)=1
43 4085 F(4)=1
44 4090 GO TO 4040
45 4100 IF K5>4 THEN 4230
46 4105 PRINT 'YOU ARE CONSTRUCTING AN 'Q$(K5);' 'N$(K3);' 'Q$(12)
47 4110 'WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.'
48 4115 PRINT 'MAXIMUM 'N$(K3);' IS='
49 4120 INPUT Q1
50 4125 ON K5 GO TO 4145,4130,4175,4220
51 4128 REM OFF-AXIS GAUSSIAN CONSTRUCTION
52 4130 'GAUSSIAN CENTERED IN ZONE OR RING'
53 4135 INPUT Q3
54 4140 GO TO 4150
55 4143 REM ON-AXIS GAUSSIAN
56 4145 Q3=0
57 4148 REM ALL GAUSSIANS CONSTRUCTED HERE.

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1-2

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58 4150 PRINT 'GAUSSIAN HALF WIDTH AT HALF HEIGHT';
59 4155 INPUT Q2
60 4160 FOR I=K1 TO K2 V(K3,I)=V(K3,I)+Q1*EXP(-.6931472*((I-Q3)/Q2)**2)
61 4170 GO TO 4420
62 4173 REM ELLIPSOIDAL PROFILE.
63 4175 PRINT 'ZONE OR RING IN WHICH ELLIPSE FALLS TO ZERO';
64 4180 INPUT Q2
65 4185 FOR I=K1 TO K2
66 4190 Q3=1.0-(I/Q2)**2
67 4195 IF Q3<0 THEN Q3=0
68 4200 V(K3,I)=V(K3,I)+Q1*SQR(Q3)
69 4205 NEXT I
70 4210 GO TO 4420
71 4219 REM HOMOGENEOUS PROFILE CONSTRUCTION.
72 4220 FOR I=K1 TO K2 V(K3,I)=V(K3,I)+Q1
73 4225 GO TO 4420
74 4227 REM OPTIONS 5 TO 10 INTERTWINED.
75 4230 IF K5>10 GO TO 4450
76 4235 K4=MOD(K5-2)
77 4237 REM K4=1 MEANS 'A FEW VALUES'; =0 MEANS 'ALL POSSIBLE VALUES.'
78 4240 K5=INT((K5-3)/2)
79 4245 PRINT 'YOU HAVE DECIDED TO 'Q5(K5+4)'; 'Q5(8+K4)'; 'H(K3)';
80 4247 PRINT 'VALUES'
81 4250 PRINT 'IN THE 'H(K3)';' PROFILE.'
82 4255 K4=K4+1
83 4260 ON K4 GO TO 4330,4265
84 4263 REM OPTION 5,7,9 OPERATE ON 'A FEW ZONES'
85 4265 PRINT 'ZONE OR RING=';
86 4270 INPUT Q1
87 4275 Q1=INT(Q1)
88 4280 IF Q1<K1 OR Q1>K2 THEN 4420
89 4285 PRINT 'VALUE=';
90 4290 INPUT Q2
91 4295 ON K5 GO TO 4300,4310,4320
92 4300 V(K3,Q1)=Q2
93 4305 GO TO 4265
94 4310 V(K3,Q1)=V(K3,Q1)*Q2
95 4315 GO TO 4265
96 4320 V(K3,Q1)=V(K3,Q1)+Q2
97 4325 GO TO 4265
98 4328 REM OPTIONS 6,8,10
99 4330 Q1=K2-K1+1
100 4335 'INPUT 'Q1';' VALUES. 1 PER LINE.'
101 4340 FOR I=K1 TO K2
102 4345 PRINT 'ZONE OR RING 'I';' VALUE=';
103 4350 INPUT T5
104 4355 Q5=Q5/(17)
105 4360 IF CNT(T5,Q5)>1 THEN 4345 ELSE Q5=Q5/(18)
106 4365 IF CNT(T5,Q5)>0 THEN 4370 ELSE 4380
107 4370 I=K1-1
108 4375 GOTO 4415
109 4380 V(S,I)=VAL(T5)
110 4385 ON K5 GO TO 4390,4400,4410
111 4390 V(K3,I)=V(S,I)
112 4395 GOTO 4415
113 4400 V(K3,I)=V(K3,I)*V(S,I)
114 4405 GO TO 4415

```

1-3

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115 4410 V(K3,I)=V(K3,I)+V(5,I)
116 4415 NEXT I
117 4420 IF F(8)=0 THEN IF K3<>1 THEN IF K3<>2 THEN RETURN
118 4422 IF F(8)<>0 THEN RETURN
119 4425 IF M1<1 THEN 4435
120 4430 FOR I=1 TO M1 V(8,I)=V(1,I)
121 4433 IF M2>50 THEN RETURN
122 4440 FOR I=M2 TO 50 V(8,I)=V(2,I)
123 4445 RETURN
124 4450 K5=K5-10
125 4455 IF K5=3 THEN 4505
126 4460 PRINT 'OVER THE APPLICABLE ZONES OR RINGS, THE '10*(9+K5)'; '
127 4465 PRINT N$(K4)'; ' PROFILE'
128 4470 PRINT 'WILL BE ADDED TO THE '1N$(K3)'; ' PROFILE.'
129 4475 PRINT 'THE RESULT IS STORED IN '
130 4480 GOSUB 15900
131 4485 PRINT 'THE UNCHANGED PROFILE IS NUMBER '1K4'; '
132 4490 K5=3-2*K5
133 4495 FOR I=K1 TO K2 V(K3,I)=V(K3,I)+K5*V(K4,I)
134 4500 GO TO 4420
135 4505 K5=K5-2
136 4510 ON K5 GO TO 4515,4550
137 4515 PRINT 'YOU ARE SCALING EVERY APPLICABLE POINT IN THE '
138 4520 PRINT N$(K3)'; ' PROFILE'
139 4525 PRINT 'BY WHATEVER VALUE YOU INPUT.'
140 4530 PRINT 'WHAT IS THE SCALE FACTOR?'
141 4535 INPUT Q1
142 4540 FOR I=K1 TO K2 V(K3,I)=Q1*V(K3,I)
143 4545 GO TO 4420
144 4550 GOSUB 15900
145 4555 PRINT 'WILL BE CROSS-MULTIPLIED WITH PROFILE '1K4'; '
146 4560 PRINT 'THE '1N$(K4)'; ' PROFILE. THE RESULTS ARE IN PROFILE '1K3'; '
147 4565 FOR I=K1 TO K2 V(K3,I)=V(K3,I)*V(K4,I)
148 4570 GOTO 4420

```

2-1

```

1 C *****
2 C *
3 C * SUBROUTINE FORWARD
4 C *
5 C * OPTIONS ARE:
6 C *
7 C * 1) USING THE MAJOR PROFILE AS A RADIAL EMISSION PROFILE AND
8 C * THE MINOR PROFILE AS THE RADIAL ABSORPTION PROFILE, COMPUTE
9 C * A LATERAL INTENSITY PROFILE AND STORE IT IN PROFILE #3.
10 C * PROFILE 4 IS USED AS THE BACKLIGHT PROFILE, AND THE
11 C * EMISSION/ABSORPTION BOUNDARY AS SET IN INITIALIZATION IS
12 C * USED. IF THE MAJOR PROFILE IS PROFILE 8, THEN THE MINOR
13 C * PROFILE IS AUTOMATICALLY ASSUMED TO BE 8, OVERRIDING THE
14 C * CHOICE MADE IN THE CALLING SEQUENCE.
15 C *
16 C * 2) CONVERT THE MAJOR PROFILE INTO A LATERAL INTENSITY
17 C * PROFILE, IGNORING ABSORPTION. ABSORBING REGIONS OF THE
18 C * INPUT AND OUTPUT PROFILES ARE IGNORED.
19 C *
20 C * 3) CONVERT THE MAJOR PROFILE INTO A LATERAL INTENSITY
21 C * (TRANSMITTANCE) PROFILE, ASSUMING ONLY ABSORPTION TAKES
22 C * PLACE. EMISSION REGION OF INPUT AND OUTPUT PROFILES ARE
23 C * NOT AFFECTED.
24 C *
25 C * 4) INSTALL RADIAL ABSORBER AS DESCRIBED IN THE MINOR PROFILE
26 C * AROUND THE LATERAL INTENSITY DATA IN THE MAJOR PROFILE.
27 C * RESULTS STORED IN THE MAJOR PROFILE, AND A TRANSMITTANCE
28 C * PROFILE IS NOT GENERATED IN THE ABSORBING REGION.
29 C *
30 C * ADDING 10 TO OPTION 2 OR 3 MAKES FORWARD IGNORE THE
31 C * ARBITRARY EMISSION/ABSORPTION BOUNDARY SET DURING INITIALIZATION.
32 C *
33 C * THUS ZONES AND RINGS EXCLUDED FROM TREATMENT IN OPTIONS 2 AND 3*
34 C * ARE TREATED IN OPTIONS 12 AND 13.
35 C *
36 C * RESULTS AUTOMATICALLY STORED IN PROFILE 3 EXCEPT WHEN OPTION 4
37 C * IS USED.
38 C *
39 C *****
40 6000 REM FORWARD...RADIAL TO LATERAL CONVERSION
41 6005 N1=L(2,1)
42 6010 N2=L(2,2)
43 6015 N3=M1
44 6020 N4=M2
45 6025 N5=D(2)
46 6030 N6=H(2,1)
47 6035 N7=H(2,2)
48 6040 IF N6=8 AND N5<3 THEN N7=8
49 6045 IF F(2)=0 THEN 6050 ELSE 6065
50 6050 IF N6=1 OR N6=2 OR N6=8 AND F(9)=0 THEN 6055 ELSE 6065
51 6055 PRINT 'NO INPUT PROFILE IN FORWARD. RETURN AND TRY AGAIN.'
52 6060 RETURN
53 6065 IF N5<1 OR N5>4 AND N5<12 AND N5<13 THEN 6070 ELSE 6080
54 6070 N5=N5
55 6075 GO TO 22000
56 6080 IF N5>10 THEN 6085 ELSE 6110
57 6085 PRINT 'EMISSION/ABSORPTION BOUNDARY AS SET PREVIOUSLY'
58 6090 PRINT 'WILL BE IGNORED IN FORWARD.'
59 6095 N5=N5-10
60 6100 IF N5=2 THEN N3=N2
61 6105 IF N5=3 THEN N4=N1
62 6110 IF N5=2 OR N5=4 THEN 6111 ELSE 6112

```

2-2

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58 6111 IF N1>N3 THEN 6115
59 6112 IF N5=3 OR N5=4 THEN IF N2<N4 THEN 6115 ELSE 6130 ELSE 6130
60 6115 PRINT 'SUBSCRIPT/OPTION CONFLICT IN FORWARD.'
61 6120 GO TO 22005
62 6130 IF N5=1 OR N5=3 THEN IF F(3)<>1 THEN 6135 ELSE 6155 ELSE 6155
63 6135 PRINT 'CONSTRUCTING DEFAULT BACKLIGHT PROFILE.'
64 6140 PRINT 'V(4,J)=100 IN ALL ZONES 1 TO 50'
65 6145 F(3)=1
66 6150 FOR I=1 TO 50 V(4,I)=100.
67 6155 IF N5=1 OR N5=3 THEN F(4)=0
68 6156 IF N2<N3 THEN N3=N2
69 6157 IF N1>N4 THEN N4=N1
70 6160 IF N5=4 THEN 6265
71 6165 REM CLEAR OUTPUT PROFILE.
72 6170 FOR I=N1 TO N2 LET V(3,I)=0
73 6175 ON N5 GO TO 6180,6180,6220
74 6180 IF N1>N3 THEN 6220
75 6185 REM RADIAL EMISSION TO LATERAL INTENSITY CONVERSION
76 6190 FOR I=N1 TO N3
77 6195 FOR J=1 TO N3
78 6200 V(3,I)=V(3,I)+A(I,J)*V(N6,J)
79 6205 NEXT J
80 6208 V(3,I)=V(3,I)*2*AI*2
81 6210 NEXT I
82 6215 IF N3=N2 OR N5=2 THEN 6305
83 6220 IF N4>N2 THEN 6305
84 6225 REM RADIAL ABSORPTION TO TRANSMITTANCE CONVERSION.
85 6230 FOR I=N4 TO N2
86 6235 FOR J=1 TO N2
87 6240 V(3,I)=V(3,I)+A(I,J)*V(N7,J)
88 6245 NEXT J
89 6250 V(3,I)=V(4,I)*10*(-V(3,I)*AI*2)
90 6255 NEXT I
91 6260 IF N5=3 THEN 6305
92 6265 IF N5<>4 THEN N6=3
93 6270 REM SURROUND EMITTER WITH ABSORBER
94 6272 IF N1>N3 OR N4>N2 THEN 6115
95 6275 FOR I=N1 TO N3
96 6280 OI=0
97 6285 FOR J=N4 TO N2 OI=OI+A(I,J)*V(N7,J)
98 6290 V(N6,I)=V(N6,I)*10*(-OI*AI)
99 6295 NEXT I
100 6300 N6=N(2,1)
101 6305 IF N5<3 THEN 6310 ELSE 6320
102 6310 PRINT 'IN FORWARD, PROFILE 'N6', THE 'N6(N6)'; PROFILE'
103 6315 PRINT 'WAS USED AS AN INPUT RADIAL EMISSION PROFILE.'
104 6320 IF N5<>2 THEN 6325 ELSE 6335
105 6325 PRINT 'IN FORWARD, PROFILE 'N7', THE 'N6(N7)'; PROFILE'
106 6330 PRINT 'WAS USED AS AN INPUT RADIAL ABSORPTION PROFILE.'
107 6335 PRINT 'OPERATING LIMITS WERE ZONES AND RINGS 'N1' TO 'N2'.'
108 6340 PRINT 'OPTION 'N5' WAS EXECUTED IN FORWARD.'
109 6350 PRINT 'OPERATION DESCRIPTION:'
110 6355 ON N5 GO TO 6360,6375,6385,6395
111 6360 PRINT 'COMPLETE RADIAL TO LATERAL EMISSION/ABSORPTION '
112 6365 PRINT 'CALCULATION PERFORMED.'
113 6370 RETURN
114 6375 PRINT 'RADIAL EMISSION TO LATERAL INTENSITY '

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2-3

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115 6380 GO TO 6365
116 6385 PRINT 'RADIAL ABSORPTION TO TRANSMITTANCE PROFILE '
117 6390 GO TO 6365
118 6395 PRINT 'INTENSITY PROFILE IN PROFILE 'IN6', THE 'IN*(N6)' PROFILE'
119 6400 PRINT 'WAS ATTENUATED ASSUMING AN ABSORBER AS DESCRIBED'
120 6405 PRINT 'IN PROFILE 'IN7' ABOVE.'
121 6410 RETURN
```

3-1

```

1  C *****
2  C *
3  C * SUBROUTINE NOISE
4  C *
5  C * OPTIONS ARE:
6  C * 1) ADD NOISE INDEPENDENT OF THE VALUE OF THE INPUT NOISELESS
7  C * DATA.
8  C * 2) ADD NOISE BASED ON THE MAXIMUM DATA VALUE IN THE EMISSION
9  C * REGION OF THE INPUT DATA PROFILE.
10 C * 3) ADD NOISE BASED ON THE MAXIMUM VALUE IN THE ABSORPTION
11 C * REGION OF THE INPUT DATA PROFILE.
12 C * 4) ADD NOISE PROPORTIONAL TO THE NOISELESS DATUM VALUE.
13 C * 14) ADD NOISE PROPORTIONAL TO THE SQUARE ROOT OF THE NOISELESS
14 C * DATUM VALUE.
15 C * 24) ADD NOISE WHICH IS PROPORTIONAL TO AN ARBITRARY POWER OF THE
16 C * NOISELESS DATUM VALUES.
17 C *
18 C *****
19 12000 REM SUBROUTINE NOISE
20 12005 S=T=0
21 12010 GOSUB 15930
22 12035 IF K5<0 OR K5>4 AND K5<>14 AND K5<>24 THEN 12090
23 12040 IF M1<1 AND K5=2 OR M2>50 AND K5=3 THEN 12090
24 12045 PRINT 'THIS IS THE NOISE ADDITION SUBROUTINE.'
25 12050 GOSUB 15900
26 12055 PRINT 'WILL HAVE NOISE ADDED TO IT AS PER YOUR OPTION CHOICE.'
27 12060 PRINT 'THE NOISELESS DATA INPUT IS SAVED IN PROFILE 'K4','
28 12065 PRINT 'THE 'N$(K4)'' PROFILE.'
29 12070 GOSUB 22020
30 12075 'OPTION 'K5' WILL BE EXECUTED.'
31 12080 FOR I=K1 TO K2 V(N4,I)=V(K3,I)
32 12085 IF K5<5 THEN 12270 ELSE 12120
33 12090 'ILLEGAL OR INCOMPATIBLE OPTION IN NOISE ROUTINE.'
34 12095 'OPTION 'K5' WAS CHOSEN.'
35 12100 'IF OPTION 2 OR 3 WERE USED, CHECK FOR THE ABSENCE OF'
36 12105 'EITHER THE EMISSION REGION OR THE ABSORPTION REGION.'
37 12110 GO TO 22005
38 12120 IF K5=14 THEN 12140
39 12125 PRINT 'UPON WHAT POWER OF THE DATA DOES NOISE DEPEND?'
40 12130 INPUT N1
41 12135 GO TO 12145
42 12140 N1=.5
43 12145 PRINT 'SCALING CHOICE. DO YOU WISH TO SCALE NOISE ON AN'
44 12150 PRINT 'ABSOLUTE BASIS OR ON AN OPTIMUM SIGNAL TO NOISE RATIO?'
45 12155 PRINT 'BASIS?'
46 12160 PRINT 'ENTER 'ABS' OR 'SN'.'
47 12165 INPUT T8
48 12170 PRINT 'NOISE IS PROPORTIONAL TO THE 'N1' POWER OF THE DATA.'
49 12175 IF T8='ABS' THEN 12180 ELSE IF T8='SN' THEN 12195 ELSE 12160
50 12180 PRINT 'SCALED BY A FACTOR OF'
51 12185 INPUT T
52 12190 GO TO 12220
53 12195 PRINT 'WITH MAXIMUM SIGNAL TO NOISE RATIO'
54 12200 INPUT T
55 12205 GOSUB 12245
56 12210 REM SUBROUTINE RETURNS S, THE MAX. INPUT DATA VALUE.
57 12215 T=(S*(1-N1))/T

```

3-2

```

58 12220 FOR I=K1 TO K2
59 12225 IF ABS(V(K3,I))<1.E-18 THEN 12235
60 12230 V(K3,I)=V(K3,I)+T*ABS(V(K3,I))*N1*(RND-.5)
61 12235 NEXT I
62 12240 RETURN
63 12245 FOR I=K1 TO K2
64 12250 IF ABS(V(K3,I))>>S THEN S=ABS(V(K3,I))
65 12255 NEXT I
66 12260 IF S=0 THEN S=1
67 12265 RETURN
68 12270 ON K5 GO TO 12280,12295,12395,12410
69 12280 PRINT 'IN ABSOLUTE UNITS, WHAT IS PEAK-TO-PEAK NOISE VALUE?'
70 12285 INPUT T
71 12290 GO TO 12350
72 12295 K1=M1
73 12300 K2=M1
74 12305 PRINT 'NOISE BASED ON MAXIMUM EMISSION REGION DATA VALUE.'
75 12310 GOSUB 12245
76 12315 K1=L(3,1)
77 12320 K2=L(3,2)
78 12330 PRINT 'WHAT IS SIGNAL TO NOISE RATIO AT HIGHEST DATA VALUE?'
79 12340 INPUT T
80 12345 T=S/T
81 12350 FOR I=K1 TO K2
82 12355 V(K3,I)=V(K3,I)+T*(RND-.5)
83 12358 NEXT I
84 12360 RETURN
85 12385 K1=M2
86 12390 K2=S0
87 12395 PRINT 'NOISE BASED ON MAXIMUM ABSORPTION REGION DATA VALUE.'
88 12405 GO TO 12310
89 12410 M1=1
90 12415 GO TO 12145

```

4-1

```

1  C *****
2  C *
3  C * SUBROUTINE SHIFT
4  C *
5  C * OPTIONS ARE
6  C * 1) SHIFT MAJOR PROFILE. EMISSION/ABSORPTION BOUNDARY FIXED.
7  C * REFLECT AND FILL TO COMPLETE PROFILE AS NECESSARY.
8  C * 2) SAME AS 1) EXCEPT THAT EMISSION/ABSORPTION BOUNDARY IS SHIFTED
9  C * IN THE SAME MANNER AS THE PROFILE.
10 C * 3) SAME AS 1) EXCEPT THAT EMISSION/ABSORPTION BOUNDARY IS
11 C * IGNORED COMPLETELY.
12 C * 4) UNSHIFT PROFILE CURRENTLY IN STORAGE AND PLACE IT IN THE
13 C * MAJOR PROFILE.
14 C * 5) REINITIALIZE SYSTEM.
15 C * 6) RESET EMISSION/ABSORPTION BOUNDARY.
16 C *
17 C * ADDING 10 TO OPTIONS 1 THROUGH 3 CANCELS REFLECTION AND FILLING.
18 C * PROFILES OTHER THAN THOSE SPECIFIED IN THE SUBROUTINE CALL MAY BE
19 C * SHIFTED UNDER SPECIAL CIRCUMSTANCES, DESCRIBED FULLY IN THE
20 C * FULL PROGRAM DOCUMENTATION.
21 C *
22 C *****
23 14000 REM SUBROUTINE SHIFT
24 14010 GOSUB 15930
25 14035 IF K5<1 OR K5>6 THEN 14040 ELSE 14060
26 14040 IF K5<11 OR K5>13 THEN 14045 ELSE 14060
27 14045 GO TO 22000
28 14060 IF K5<>5 AND K5<>6 THEN 14062
29 14061 GOSUB 22020
30 14062 IF K5>3 AND K5<7 THEN 14600
31 14065 IF K5=2 THEN F(1)=M1
32 14070 PRINT 'BY HOW MANY ZONES DO YOU WISH TO SHIFT THE PROFILE?'
33 14075 INPUT I$
34 14080 Q1=0
35 14085 FOR I=6 TO 31
36 14090 LET T$=PUT$(T$,1,I)
37 14095 Q1=Q1+CNT(I$,T$)
38 14100 IF Q1>0 THEN 22005
39 14105 NEXT I
40 14110 IF LEN(I$)>4 THEN 22005
41 14115 K6=VAL(I$)
42 14120 IF K6<>INT(K6) THEN 14125 ELSE 14140
43 14125 PRINT 'NON-INTEGER SHIFTS ARE ILLEGAL. TRY AGAIN.'
44 14135 GO TO 14070
45 14140 IF K6<-50 OR K6>100 THEN 14150 ELSE 14165
46 14150 PRINT 'SHIFT AMOUNT IS <-50 OR >100.'
47 14155 PRINT 'YOU'RE WIPING OUT THE PROFILE. TRY AGAIN.'
48 14160 GO TO 14070
49 14165 GOSUB 15900
50 14170 PRINT 'WILL BE SHIFTED 'K6' RINGS OR ZONES.'
51 14175 IF K5>10 THEN PRINT 'NO REFLECTION OR BACKFILLING WILL OCCUR.'
52 14180 IF K5=2 OR K5=12 THEN PRINT 'M1 SHIFTED ALSO.'
53 14185 IF K5=3 OR K5=13 THEN PRINT 'M1 IGNORED.'
54 14190 IF K6=0 THEN RETURN
55 14195 IF K3=K4 AND K3<>3 THEN K7=14 ELSE K7=13
56 14200 PRINT 'UNSHIFTED PROFILE STORED IN PROFILE NUMBER 'K7
57 14205 FOR I=K1 TO K2

```


4-2

```

58 14210 U(K7,I)=U(K3,I)
59 14215 U(K3,I)=0
60 14220 NEXT I
61 14225 IF K5=1 OR K5=11 THEN 14345
62 14230 REM OPTION 2,3,12, AND 13
63 14235 N1=N4-K1
64 14240 N2=N5-K2
65 14245 N3=1
66 14250 GOSUB 14810
67 14255 IF K5=3 OR K5=13 THEN 14275
68 14260 M1=F(1)+K6
69 14265 IF M1<1 THEN M1=0 ELSE IF M1>50 THEN M1=50
70 14270 M2=M1+1
71 14275 IF K5>10 THEN 14500 ELSE IF K6>0 THEN 14315
72 14280 IF K2>M2 AND K3=3 THEN 14290 ELSE 14500
73 14285 N3=3
74 14290 N4=K2+K6+1
75 14295 IF N4<K1 THEN N4=N1
76 14300 IF N4>K2 GO TO 14500
77 14305 GOSUB 14810
78 14310 GO TO 14500
79 14315 N5=K1+K6-1
80 14320 N3=2
81 14325 IF N5>K2 THEN N5=K2
82 14330 GOSUB 14810
83 14335 GO TO 14500
84 14340 REM OPTIONS 1 AND 11
85 14345 IF K1>M1 THEN 14405
86 14350 PRINT 'EMISSION-ABSORPTION BOUNDARY FIXED AND EMPLOYED.'
87 14355 N1=N4-K1
88 14360 N2=N5-N1
89 14365 N3=1
90 14370 GOSUB 14810
91 14375 IF K5>10 OR K6<0 THEN 14405
92 14380 N5=K1+K6+1
93 14385 N3=2
94 14390 IF N5>K2 THEN N5=K2
95 14395 IF N5>N1 THEN N5=N1
96 14400 GOSUB 14810
97 14405 IF K2<N2 THEN 14500
98 14410 N1=N2
99 14415 IF N1<K1 THEN N1=K1
100 14420 N2=N5-K2
101 14425 N3=1
102 14430 N4=N1
103 14435 GOSUB 14810
104 14440 IF K5>10 THEN 14500
105 14445 IF K6<0 AND K3=3 THEN 14475
106 14450 N3=2
107 14455 N5=K1+K6-1
108 14460 IF N5>N2 THEN N5=K2
109 14465 GOSUB 14810
110 14470 GO TO 14500
111 14475 N3=3
112 14480 N4=K2+K6+1
113 14485 IF N4<N2 THEN N4=N2
114 14490 IF N4>K2 THEN 14500

```

4-3

```

115 14495 GOSUB 14810
116 14500 IF K3<>3 OR K4=K3 THEN RETURN
117 14505 REM AUTOBACKGROUND AND BACKLIGHT SHIFTING
118 14510 IF K2<M2 THEN 14590
119 14515 N1=K1
120 14520 IF N1<M2 THEN N1=M2
121 14525 N2=K2
122 14530 FOR I=K1 TO K2
123 14535 Q1=I+K4
124 14540 IF N1<Q1 OR N2>Q1 THEN 14550
125 14545 V(4+Q1)=V(4+I)
126 14550 NEXT I
127 14555 IF K6>0 THEN N1=M2
128 14560 IF N1<K1 THEN N1=K1
129 14565 IF K6<0 THEN N1=K2+K6+1
130 14570 IF K6>0 THEN N2=F(1)+K6-1
131 14575 IF N2<K2 OR N6<0 THEN N2=K2
132 14580 FOR I=N1 TO N2 V(4+I)=100.
133 14585 PRINT 'BACKLIGHT PROFILE, NUMBER 4, HAS BEEN SHIFTED.'
134 14590 K3=K4
135 14595 GO TO 14165
136 14598 REM OPTIONS 4,5,6
137 14600 K5=K5-3
138 14605 ON K5 GO TO 14610,14660,14680
139 14610 PRINT 'UNSHIFT PRESENT PROFILE(S)'.
140 14615 IF K3=K4 AND K3<>3 THEN K7=14 ELSE K7=13
141 14620 FOR I=N1 TO K2 V(K3+I)=V(K7+I)
142 14625 GOSUB 15900
143 14630 PRINT 'IS BEING UNSHIFTED, AS IS M1.'
144 14635 M1=F(1)
145 14640 M2=M1+1
146 14645 IF K3<>3 OR K4=K3 THEN RETURN
147 14650 K3=K4
148 14655 GO TO 14615
149 14660 REM REINITIALIZE SYSTEM
150 14665 PRINT 'REINITIALIZING SYSTEM'
151 14670 GOSUB 3001
152 14675 RETURN
153 14680 PRINT 'RESET LAST EMISSION RING NUMBER.'
154 14685 PRINT 'YOUR CHOICE':
155 14690 INPUT F(1)
156 14695 F(1)=INT(F(1))
157 14700 IF F(1)<0 THEN F(1)=0 ELSE IF F(1)>50 THEN F(1)=50
158 14705 M1=F(1)
159 14710 M2=F(1)+1
160 14715 RETURN
161 14800 REM SUBROUTINE SHFTER
162 14805 REM UTILITY ROUTINE FOR SUBROUTINE SHIFT
163 14810 ON N3 GO TO 14815,14845,14875
164 14815 FOR I=N4 TO N5
165 14820 Q1=I-K6
166 14825 IF Q1<N1 OR Q1>N2 THEN 14835
167 14830 V(K3+I)=V(K7+Q1)
168 14835 NEXT I
169 14840 RETURN
170 14845 FOR I=N4 TO N5
171 14850 Q1=K6-I+1

```

4-4

```
172 14855 IF Q1<N1 OR Q1>N2 THEN 14865
173 14860 V(K3,I)=V(K7,Q1)
174 14865 NEXT I
175 14870 RETURN
176 14875 FOR I=N4 TO N5 V(K3,I)=100.
177 14880 RETURN
```

5-1

```

1  C *****
2  C *
3  C * SUBROUTINE ABEL
4  C *
5  C * OPTION ARE
6  C * 1) PERFORM ABEL INVERSION TAKING EMISSION/ABSORPTION BOUNDARY
7  C * AS CORRECT. GIVES PROPER DREAMS MODEL INVERSION.
8  C * 2) INVERT MAJOR PROFILE ASSUMING A TOTALLY EMITTING PROFILE.
9  C * 3) INVERT MAJOR PROFILE ASSUMING A TOTALLY ABSORBING PROFILE.
10 C * 4) TAKE EMISSION INTENSITY FROM MAJOR PROFILE AND ABSORBING
11 C * SPECIES DISTRIBUTION FROM MINOR PROFILE. PERFORM LATERAL
12 C * TO RADIAL INVERSION ON EMISSION INTENSITY DATA.
13 C *
14 C * OUTPUT IS TO PROFILE 4 EXCEPT IF OPTION 2 IS CHOSEN;
15 C * IN THAT CASE, OUTPUT MAY BE DIRECTED TO EITHER PROFILE 4 OR 7.
16 C * WITH THE CHOICE BEING MADE WITHIN THE SUBROUTINE, NOT IN THE
17 C * CONTROL ROUTINE.
18 C *
19 C *****
20 16000 REM ABEL INVERSION SUBROUTINE
21 16010 GOSUB 15930
22 16035 K6=K4
23 16040 K7=6
24 16045 IF K5<=0 OR K5>4 THEN 16090
25 16050 IF F(3)=0 THEN IF K5=1 OR K5=3 THEN 16105
26 16055 GOSUB 22020
27 16060 PRINT 'THE LATERAL TO RADIAL INVERSION WILL BE PERFORMED.'
28 16075 GOSUB 15900
29 16080 PRINT 'WILL BE USED AS AN INPUT LATERAL INTENSITY PROFILE.'
30 16085 ON K5 GO TO 16125,16145,16125,16195
31 16090 GO TO 23000
32 16105 PRINT 'DEFAULT BACKLIGHT PROFILE WILL BE CONSTRUCTED.'
33 16110 F(3)=1
34 16115 FOR I=1 TO 50 V(K6,I)=100.
35 16120 GO TO 16055
36 16125 PRINT 'PROFILE 'K4' IS THE BACKLIGHT INTENSITY PROFILE.'
37 16130 IF K5=3 THEN 16185
38 16135 PRINT 'A FULL DREAMS INVERSION WILL BE PERFORMED.'
39 16140 GO TO 16225
40 16145 K7=7
41 16150 PRINT 'AN INVERSION WILL BE PERFORMED '
42 16155 PRINT 'ASSUMING A PURELY EMITTING PROFILE.'
43 16160 PRINT 'OUTPUT WILL BE TO PROFILE 7 UNLESS YOU INPUT THE NUMERAL'
44 16165 PRINT '4 IN RESPONSE TO THE NEXT QUESTION MARK.'
45 16170 INPUT I#
46 16175 IF I#='4' THEN K7=6
47 16180 GO TO 16225
48 16185 PRINT 'INVERSION OF A PURELY ABSORBING PROFILE IS ASSUMED.'
49 16190 GO TO 16225
50 16195 K3=K4
51 16196 GOSUB 15900
52 16197 K3=K4
53 16200 PRINT 'IS THE ASSUMED RADIAL ABSORPTION DISTRIBUTION.'
54 16205 K6=4
55 16210 PRINT 'THE LATERAL PROFILE OBSERVED IS ASSUMED TO HAVE BEEN'
56 16215 PRINT 'ATTENUATED BY THE ABSORBER IN PROFILE 'K4'.'
57 16220 PRINT 'AND THE CALCULATIONS ARE DONE ACCORDINGLY.'

```

5-2

```

58 14225 FOR I=K1 TO K2
59 14230 V(15,I)=0
60 14235 V(K7,I)=0
61 14240 NEXT I
62 14245 PRINT 'OUTPUT IS TO PROFILE NUMBER 'K7
63 14250 IF K5=2 OR K5=4 THEN 14295
64 14255 IF F(4)<0 AND F(5)<1 THEN 14260 ELSE 14285
65 14260 PRINT 'FLAGS DISALLOW RADIAL TO LATERAL CONVERSION IN ABEL'
66 14265 PRINT 'SUBROUTINE. F(4)='F(4), 'F(5)='F(5)
67 14270 GO TO 22005
68 14280 REM INVERT ABSORPTION REGION
69 14285 IF K5=2 OR M1=50 OR K5=4 OR K2<=M1 AND K5<>3 THEN 14370
70 14290 IF K5=3 OR K1<=M2 THEN K8=K1 ELSE K8=M2
71 14300 FOR I=K8 TO K2
72 14305 FOR J=1 TO K2
73 14310 IF V(K6,J)=0 THEN 14315 ELSE 14330
74 14315 PRINT 'V('K6;','J')=0, WHICH IS AN ILLEGAL BACKLIGHT '
75 14320 PRINT 'INTENSITY VALUE. RETURN AND CORRECT ERROR.'
76 14325 RETURN
77 14330 V(K7,I)=V(K7,I)+B(I,J)*LGT(V(K6,J)/V(K3,J))
78 14335 NEXT J
79 14340 V(K7,I)=V(K7,I)*.5*A2
80 14345 NEXT I
81 14350 IF K5=3 THEN RETURN
82 14355 REM COMPENSATE INTENSITY PROFILE FOR ABSORPTION EFFECTS.
83 14360 REM AND STORE COMPENSATED PROFILE IN V(16,4).
84 14365 REM IF NO ABSORPTION, SIMPLY TRANSFER INTENSITY DATA TO V(15,J).
85 14370 IF K2<=M1 OR K5=2 THEN 14465
86 14375 IF K1>M1 THEN 14475
87 14380 REM AT THIS POINT, ONLY K5=1 OR K5=4 MAY EXECUTE.
88 14385 IF K5=1 THEN K9=K7 ELSE K9=K4
89 14390 FOR I=K1 TO M1
90 14395 FOR J=M2 TO K2
91 14400 V(15,I)=V(15,I)+A(I,J)*V(K9,J)
92 14405 NEXT J
93 14410 V(15,I)=V(K3,I)*10**(V(15,I)*A1)
94 14415 NEXT I
95 14420 REM CONVERT INTENSITY TO EMISSION
96 14425 IF K5=2 THEN K9=K2 ELSE K9=M1
97 14430 FOR I=K1 TO K9
98 14435 FOR J=1 TO K9
99 14440 V(K7,I)=V(K7,I)+B(I,J)*V(15,J)
100 14445 NEXT J
101 14450 V(K7,I)=V(K7,I)*.5*A2**2
102 14455 NEXT I
103 14460 RETURN
104 14465 FOR I=K1 TO K2 V(15,I)=V(K3,I)
105 14470 GO TO 14425
106 14475 IF K5=1 THEN RETURN
107 14480 'INTENSITY DATA NOT WITHIN OPERATING ZONES IN SUBROUTINE ABEL.'
108 14485 PRINT 'USE YOUR JUDGEMENT--THIS MAY BE INCONSEQUENTIAL.'
109 14490 RETURN

```

6-1

```

1 C *****
2 C *
3 C * SUBROUTINE PRINT-PLOT
4 C *
5 C * OPTIONS ARE
6 C * 1) PLOT USING DEAN STUELAND'S MINI-PLOT ROUTINE (WITH OPTIONS
7 C *   HARDWIRED).
8 C * 2) PLOT USING DEAN STUELAND'S PEPSUB ROUTINE (WITH MOST OPTIONS
9 C *   HARDWIRED).
10 C * 3) PLOT USING FIRST MINI-PLOT AND THEN PEPSUB.
11 C * 10) PRINT A LISTING OF THE CONTENTS OF THE MAJOR PROFILE AND
12 C *   THE BASE 10 LOG OF SAID DATA.
13 C * 11) THROUGH 13) COMBINE OPTION 10 WITH OPTIONS 1 THROUGH 3
14 C *   RESPECTIVELY.
15 C *
16 C * ALL OPERATIONS USE ONLY THE MAJOR PROFILE. THE MINOR PROFILE
17 C * IS IRRELEVANT.
18 C *
19 C *****
20 8000 REM OUTPUT ROUTINE
21 8001 GOSUB 15930
22 8010 Q2=K1-1
23 8020 IF K5<1 OR K5>13 THEN 8030 ELSE IF K5>3 AND K5<10 THEN 8030
24 8025 IF K5>=10 THEN 8050 ELSE 8140
25 8030 GO TO 22000
26 8050 K5=K5-10
27 8055 PRINT 'HOME'
28 8040 INPUT Q#
29 8045 PRINT ' '
30 8048 GO TO 8100
31 8070 IF K2>=M2 THEN 8210
32 8075 T#='NO'
33 8080 S#='YES'
34 8085 GO TO 8247
35 8100 PRINT 'PROFILE 'K3', THE 'H(K3)' PROFILE IS PRINTED BELOW.'
36 8105 PRINT ' '
37 8110 PRINT 'INDEX',H(K3),'LOG U(I,J)'
38 8115 Q#=H(K3)
39 8115 FOR I=K1 TO K2
40 8120 IF U(K3,I)<>0 THEN Q4=LOG(ABS(U(K3,I))) ELSE Q4=-12345.
41 8125 IF LEN(Q#)<16 THEN PRINT,I,U(K3,I),Q4 ELSE PRINT,I,U(K3,I),,Q4
42 8130 NEXT I
43 8135 PRINT ' '
44 8140 IF K5=0 THEN RETURN
45 8145 F(7)=0
46 8145 FOR I=K1 TO K2
47 8150 X(I-Q2)=I
48 8155 Y(I-Q2)=U(K3,I)
49 8160 NEXT I
50 8170 T#='EMISSION'
51 8175 Y4#=' '
52 8180 IF CNT(H(K3),T#)>0 THEN Y4#=Q#(15)
53 8185 T#='RADIAL'
54 8190 IF CNT(H(K3),T#)>0 THEN Y4#=Q#(15)
55 8195 T#='EPSILON'
56 8200 IF CNT(H(K3),T#)>0 THEN Y4#=Q#(15)
57 8205 IF Y4#<>Q#(15) THEN Y4#=Q#(16)

```

6-2

```

58      8208 GO TO 8070
59      8210 PRINT 'PLOT OPTIONS. SHOULD ABSORPTION REGION'S PLOT '
60      8212 PRINT 'SYMBOL BE DISTINCT'
61      8215 INPUT T$
62      8220 IF CNT(T$,Q$(17))>0 AND T$<>'YES' THEN 8210
63      8225 IF T$='O' OR T$='-2' OR T$='YES' OR T$='Y' THEN T$='YES' ELSE T$='NO'
64      8230 IF T$='NO' THEN PRINT 'SAME PLOT SYMBOL USED THROUGHOUT.'
65      8235 IF T$='YES' THEN PRINT 'PLOT HAS 2 DIFFERENT SYMBOLS.'
66      8240 PRINT 'SHOULD ABSORPTION REGION BE SCALED THE SAME AS '
67      8242 PRINT 'THE EMISSION REGION'
68      8245 INPUT S$
69      8247 Q1$=S$
70      8250 IF CNT(S$,Q$(17))>0 AND S$<>'YES' THEN 8240
71      8255 Q3=Q4=Q5=Q6=Q7=Q8=0
72      8260 IF Q1$='Y' OR Q1$='O' OR Q1$='-2' OR Q1$='YES' THEN Q1$='YES' ELSE Q1$='NO'
73      8265 IF K2-K1<1 THEN 8270 ELSE 8280
74      8270 'TOO FEW POINTS. PLOTTING ABANDON.'
75      8275 RETURN
76      8280 IF K1>M1 THEN 8295
77      8285 FOR I=K1 TO M1
78      8287 IF V(K3,I)>Q4 THEN Q4=V(K3,I)
79      8289 NEXT I
80      8290 FOR I=K1 TO M1
81      8292 IF V(K3,I)<Q3 THEN Q3=V(K3,I)
82      8294 NEXT I
83      8295 IF K2<M2 THEN 8310
84      8300 FOR I=M2 TO K2
85      8302 IF V(K3,I)>Q6 THEN Q6=V(K3,I)
86      8304 NEXT I
87      8305 FOR I=M2 TO K2
88      8307 IF V(K3,I)<Q5 THEN Q5=V(K3,I)
89      8309 NEXT I
90      8310 IF Q1$='YES' OR K2<M2 OR K1>M1 THEN 8315 ELSE 8340
91      8315 IF Q6>Q4 THEN Q4=Q6
92      8320 IF Q5<Q3 THEN Q3=Q5
93      8325 IF T$='NO' OR K1>M1 OR K2<M2 THEN Q2=K2-K1+1 ELSE Q2=M1-K1+1
94      8328 IF Q2<K2-K1+1 THEN F(7)=1 ELSE F(7)=0
95      8330 GO TO 8445
96      8335 REM DATA ON BOTH SIDES OF BOUNDARY, SCALED DIFFERENTLY
97      8340 IF T$='YES' THEN Q2=M1-K1+1 ELSE Q2=K2-K1+1
98      8345 IF Q3=0 AND Q5=0 THEN 8350 ELSE 8365
99      8350 IF Q6<>0 AND Q4<>0 THEN Q7=Q4/Q6
100     8351 IF Q6<>0 AND Q4=0 THEN Q4=Q6
101     8352 IF Q6=Q4 OR Q6=0 THEN 8445
102     8355 GO TO 8420
103     8365 IF Q4=0 AND Q6=0 THEN 8370 ELSE 8385
104     8370 IF Q5<>0 AND Q3<>0 THEN Q7=Q3/Q5
105     8372 IF Q5<>0 AND Q3=0 THEN Q3=Q5
106     8374 IF Q5=Q3 THEN 8445 ELSE IF Q5=0 THEN 8445
107     8375 GO TO 8420
108     8383 REM SOME + AND SOME - VALUES.
109     8385 IF Q5=0 AND Q6=0 THEN 8445
110     8387 IF Q3=0 AND Q4=0 THEN 8389 ELSE 8395
111     8389 Q3=Q5
112     8391 Q4=Q6
113     8393 GO TO 8445
114     8395 IF Q5=0 AND Q4<>0 THEN Q7=Q4/Q6

```

6-3

```

115 8397 IF Q4=0 AND Q3<>0 THEN Q7=Q3/Q5
116 8400 IF Q7<>0 THEN 8420
117 8402 IF Q3=0 AND Q4=0 THEN 8424
118 8404 IF Q3=0 THEN 8432
119 8406 IF Q4=0 AND Q5=0 THEN 8428
120 8408 IF Q4=0 THEN 8436
121 8410 Q7=Q3/Q4
122 8412 Q8=Q5/Q6
123 8414 IF ABS(Q8)>ABS(Q7) THEN Q3=Q8*Q4 ELSE Q4=Q3/Q8
124 8418 IF ABS(Q6)\ABS(Q5) THEN Q7=Q4/Q6 ELSE Q7=Q3/Q5
125 8420 FOR I=M2 TO K2 Y(I-K1+1)=Q7*Y(I-K1+1)
126 8421 F(7)=1
127 8422 GO TO 8445
128 8424 Q3=-Q5**2/Q4
129 8426 GO TO 8397
130 8428 Q4=ABS(Q6**2/Q3)
131 8430 GO TO 8395
132 8432 Q3=Q4*Q5/Q6
133 8434 GO TO 8410
134 8436 Q4=Q3/Q5*Q6
135 8438 GO TO 8410
136 8445 IF K5=2 THEN 8500
137 8450 GOSUB 10009
138 8451 F(7)=0
139 8453 IF Y19='ABORT' THEN RETURN
140 8455 IF (K2-K1+1)=Q2 THEN 8495
141 8460 Q7=Q2
142 8465 Q2=K2-M1
143 8470 FOR I=1 TO Q2
144 8475 X(I)=X(Q7+I)
145 8480 Y(I)=Y(Q7+I)
146 8483 NEXT I
147 8485 Y19='OVERLAY'
148 8490 IF Q3<>Q4 THEN GOSUB 10186
149 8493 PRINT ' '
150 8495 IF K5=3 THEN 8555 ELSE RETURN
151 8499 REM PEPSUB CALLING SEQUENCE
152 8500 GOSUB 9000
153 8502 F(7)=0
154 8503 IF Z2='ABORT' THEN Z9='ABORT'
155 8504 IF Z9='ABORT' THEN RETURN
156 8505 IF (K2-K1+1)=Q2 THEN RETURN
157 8510 Q7=Q2
158 8515 Q2=K2-M1
159 8520 FOR I=1 TO Q2
160 8525 X(I)=X(Q7+I)
161 8530 Y(I)=Y(Q7+I)
162 8535 NEXT I
163 8540 Z9='OVERLAY'
164 8545 GOSUB 9126
165 8550 RETURN
166 8555 IF Q2=K2-K1+1 THEN 8500
167 8560 FOR I=1 TO Q2
168 8565 X(Q7+I)=X(I)
169 8570 Y(Q7+I)=Y(I)
170 8575 NEXT I
171 8580 Q2=K2-K1+1-Q2

```


6-4

```
172 8590 FOR I=K1 TO Q2 X(I-K1+1)=I
173 8595 FOR I=K1 TO Q2 Y(I-K1+1)=V(K3,I)
174 8598 F(7)=1
175 8600 GO TO 8500
```

```

176 C *****
177 C *
178 C * MODIFIED PEPSUB.
179 C *
180 C *****
181 9000 REM THIS IS A MODIFICATION OF PEPSUB.
182 9002 REM PEPSUB WAS WRITTEN BY DEAN STUELAND.
183 9004 REM MODIFIED BY A. SCHEELINE 6/7/73 AND 6/8/77.
184 9018 IF Z1=0 THEN 9114
185 9020 LET Z1=0
186 9022 LET Z1$='XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX'
187 9024 LET Z3$='0.0000000000 0.0000000000'
188 9028 'A) ENABLE HARD COPY PLOTTING'
189 9030 INPUT Z2$
190 9031 IF Y1$='ABORT' THEN Z2$='ABORT'
191 9032 IF Z2$='-1' THEN 9484
192 9033 IF Z2$='ABORT' THEN 9484
193 9034 IF Z2$='-2' THEN LET Z2$='YES'
194 9036 IF Z2$='NO' OR Z2$='YES' THEN 9042
195 9038 ''
196 9040 GO TO 9028
197 9042 IF Z2$='NO' THEN LET Z7$=' ' ELSE LET Z7$='RGSP.PT'
198 9044 IF Z2$='NO' THEN 9078
199 9046 Z2=10.8
200 9078 ''
201 9082 OPEN PLOT FOR SYMBOLIC OUTPUT AS FILE 9
202 9084 LET Z9=0
203 9088 IF Z7$=◇ ' THEN PRINT ON 9 IN IMAGE Z1:Z7$
204 9090 IF Z7$=' ' THEN 9110
205 9104 LET Z5$='PLOTTER PEN/LIQ'
206 9108 PRINT ON 9 IN IMAGE Z1:Z5$
207 9110 LET Z2$='EXOT CHEMISTRY*WALTERS.BASIC-PEP'
208 9112 PRINT ON 9 IN IMAGE Z1:Z2$
209 9114 PRINT ON 9 IN IMAGE 'ZZ.ZZZX':Z2
210 9116 LET Z1=Z1+1
211 9117 LET X5=0
212 9118 IF Z4=5 THEN 9704
213 9120 ''
214 9121 LET Z9=0
215 9122 'D) PLOT STATUS'
216 9124 INPUT Z1
217 9126 IF Z1$='-1' THEN LET Z9=-1
218 9127 IF Z9=-1 AND Z4>1 THEN LET Z3=2
219 9129 IF Z9=-1 THEN Z1$='ABORT'
220 9130 IF Z1$='-2' THEN LET Z1$='NEW'
221 9131 IF Y1$='ABORT' THEN Z1$='ABORT'
222 9132 LET Z3=0
223 9133 IF Z1$='ABORT' THEN 9484
224 9134 IF Z1$='NEW' THEN Z3=1
225 9136 IF Z1$='OVERLAY' THEN LET Z3=2
226 9138 IF Z1$='LAST' THEN LET Z3=3
227 9140 IF Z1$='DONE' THEN LET Z3=4
228 9142 IF Z1$='CLOSE' THEN LET Z3=4
229 9144 IF Z3=0 THEN 9118
230 9146 IF Z3=2 AND Z4=2 THEN 9160
231 9148 IF Z3>2 THEN 9160
232 9150 IF Z3=2 AND Z4=1 THEN 9160

```

6-6

```

233 9152 ' '
234 9154 '**YOU CANNOT DO AN OVERLAY WITHOUT AT LEAST'
235 9156 ' ONE NEW PLOT '
236 9158 GO TO 9118
237 9160 LET Z9=Z3
238 9162 ON Z3 GO TO 9168,9164,9168,9666
239 9164 PRINT ON 9 IN IMAGE Z18:'OVERLAY'
240 9166 GO TO 9274
241 9168 PRINT ON 9 IN IMAGE Z18:'NEW PLOT'
242 9170 Z9=-2
243 9170 LET Z9=0
244 9192 REM -- TITLE --
245 9196 Z29=M$(K3)+' '+0$(12)
246 9212 PRINT ON 9 IN IMAGE Z18:Z29
247 9220 REM -- LABEL FOR X-AXIS --
248 9224 Z29=Y48
249 9240 PRINT ON 9 IN IMAGE Z18:Z29
250 9248 REM -- Y-AXIS LABEL --
251 9250 Z29=M$(K3)
252 9244 PRINT ON 9 IN IMAGE Z18:Z29
253 9272 REM -- SYMBOL AT EACH DATA POINT --
254 9274 IF T8='NO' OR X(1)<=M1 THEN Z8=-2 ELSE Z8=4
255 9288 IF Z8=-2 OR Z8=-3 THEN 9298
256 9294 PRINT ON 9 IN IMAGE 'ZZ':Z8
257 9296 GO TO 9304
258 9298 PRINT ON 9 IN IMAGE 'ZZ':'-9'
259 9302 REM -- LINE TO CONNECT DATA POINTS --
260 9304 IF T8='NO' OR X(1)<=M1 THEN Z7=-2 ELSE Z7=1
261 9320 IF Z7=-2 OR Z7=-3 THEN 9338
262 9334 PRINT ON 9 IN IMAGE 'ZZ':Z7
263 9336 GO TO 9346
264 9338 PRINT ON 9 IN IMAGE 'ZZ':'-9'
265 9344 REM -- MAXIMUM AND MINIMUM --
266 9346 IF Z3=2 THEN 9374
267 9348 Z8=K2
268 9362 Z7=K1
269 9376 IF Z7=Z8 THEN PRINT '** THE MAX & MIN CANNOT BE EQUAL'
270 9378 IF Z7=Z8 THEN PRINT 'BUT WE FIXED THAT FOR YOU.'
271 9379 IF Z7=Z8 THEN Z8=Z8+1
272 9380 PRINT ON 9 IN IMAGE Z38: Z7,Z8
273 9382 GO TO 9390
274 9388 REM -- MAX & MIN ON Y AXIS
275 9390 LET Z4=0
276 9394 Z8=Q4
277 9410 Z7=Q3
278 9420 IF Z7<>Z8 THEN 9428
279 9422 ' '
280 9424 PRINT '** THE MAX & MIN CANNOT BE EQUAL, BUT WE'LL FIX THAT.'
281 9426 Z8=Z8+1
282 9428 PRINT ON 9 IN IMAGE Z38:Z7,Z8
283 9430 GO TO 9436
284 9434 REM -- PAGE SIZE --
285 9436 Z9=0
286 9488 PRINT ON 9 IN IMAGE Z18:'NUMBER'
287 9490 PRINT ON 9 IN IMAGE Z38:Z2,Z2
288 9492 IF Z29='-1' THEN LET Z9=-1
289 9546 IF Z9<0 THEN 9632

```

6-7

```

290 9572 REM -- INPUT FROM X & Y ARRAYS --
291 9574 Z4=02
292 9580 IF Z4<1 OR Z4>55 THEN Z9=-1
293 9582 IF Z9=-1 THEN Z4=-1
294 9584 IF Z4=-1 THEN 9632
295 9590 IF Z9<>-1 THEN PRINT ON 9 IN IMAGE Z1$:'DATAFOLLOWS' ELSE 9632
296 9592 FOR Z3=1 TO Z4
297 9594 PRINT ON 9 IN IMAGE Z3$:'X(Z3),Y(Z3)'
298 9596 NEXT Z3
299 9598 LET Z4=Z4+1
300 9600 GO TO 9634
301 9632 PRINT ON 9 IN IMAGE Z1$:'EARLY ESCAPE'
302 9634 IF Z4<3 THEN LET Z9=-1
303 9636 PRINT ON 9 IN IMAGE 'XXXXX':'-1 -1'
304 9638 IF Z9=-1 THEN PRINT ON 9 IN IMAGE Z1$:'NODATA'
305 9640 IF Z9<>-1 THEN PRINT ON 9 IN IMAGE Z1$:'ENDOFDATA'
306 9642 LET Z4=0
307 9644 REM -- END OF ONE PLOT --
308 9646 REM -- CHECK THE STATUS OF THE PLOT --
309 9648 REM -- RETURN FOR 'NEW' --
310 9650 IF Z9<>-1 THEN LET Z4=Z3
311 9651 IF Z9=-1 AND Z3=2 THEN LET Z4=1
312 9652 IF Z9=-1 THEN 9666
313 9654 IF Z3>2 THEN 9666
314 9656 IF F(7)=0 THEN PRINT ' '
315 9658 IF F(7)=0 THEN PRINT 'NORMAL RETURN'
316 9660 ' '
317 9662 RETURN
318 9664 REM -- 'RETURN' FOR LEAVING BASIC --
319 9666 LET Z2$='EOF'
320 9668 PRINT ON 9 IN IMAGE Z1$:'Z2$'
321 9670 ' '
322 9672 CLOSE 9
323 9674 'FILE HAS BEEN CLOSED'
324 9676 IF Z9='CLOSE' THEN 9696
325 9678 'EXIT FROM BASIC'
326 9680 EXEC 'BASG,A PLOT.
327 9682 EXEC 'BADD,P PLOT.
328 9684 STOP
329 9686 ' '
330 9688 'ESCAPE RETURN'
331 9690 ' '
332 9692 IF Z3<>1 THEN LET Z4=Z3 ELSE LET Z4=0
333 9694 RETURN
334 9696 'NO EXIT FROM BASIC'
335 9698 'THIS SHOULD BE THE LAST RETURN FROM THE PEP SUBROUTINE'
336 9700 LET Z4=5
337 9702 RETURN
338 9704 'FILE WAS CLOSED ON THE LAST CALL'
339 9706 'SORRY, NO MORE PLOTS FROM PEPSUB.'
340 9708 RETURN

```

6-8

```

341 C *****
342 C *
343 C * MODIFIED MINI-PLOT
344 C *
345 C *****
346 10000 REM MINILOT SUBROUTINE. WRITTEN BY DEAN STUELAND.
347 10005 REM MODIFIED BY A. SCHEELINE 8/5/75.
348 10009 LET Z0=Z0+1
349 10012 LET Y2$=""
350 10015 IF Z0>1 THEN 10027
351 10018 DIM Z(60,30)
352 10021 LET Y8$=""
353 10024 LET X1=30
354 10027 "
355 10030 'D) PLOT STATUS'
356 10033 INPUT Y1$
357 10035 IF Y1$='ABORT' THEN 10471
358 10036 IF Y1$='-2' THEN LET Y1$='NEW'
359 10039 IF Y1$='-1' THEN 10933
360 10042 IF Y1$='OVERLAY' AND Y8$='NEW' THEN 10186
361 10045 IF Y1$='OVERLAY' THEN 10060
362 10048 "
363 10051 '** YOU CANNOT HAVE AN OVERLAY WITHOUT AT LEAST ONE NEW PLOT'
364 10054 "
365 10057 GO TO 10027
366 10060 IF Y1$='NEW' THEN 10027
367 10061 LET Y8$=""
368 10063 FOR Y7=1 TO X1
369 10066 FOR Y8=1 TO 60
370 10069 LET Z(Y8,Y7)=5
371 10072 NEXT Y8
372 10075 NEXT Y7
373 10078 LET Y7=5
374 10120 Y3$=M$(K3)+' '+0$(12)
375 10140 REM Y4$ ASSIGNED EXTERNALLY.
376 10162 Y5$=M$(K1)
377 10168 LET X$=Y5$
378 10171 LET Y8=LEN(X$)
379 10174 IF Y8<=X1 THEN 10186
380 10177 "
381 10180 '** THE Y AXIS CAN HAVE NO MORE THAN 'X1' CHARACTERS'
382 10183 RETURN
383 10186 IF T$='NO' OR X(1)<=M1 THEN Y7=40 ELSE Y7=6
384 10203 IF Y1$='OVERLAY' THEN GO TO 10393
385 10240 Y2=K2
386 10255 Y1=K1
387 10264 IF Y1>Y2 THEN EXCHANGE Y1,Y2
388 10267 IF Y2>Y1 THEN 10276
389 10270 '** THE MAX & MIN CANNOT BE EQUAL'
390 10273 RETURN
391 10276 Y4=04
392 10297 Y3=03
393 10306 IF Y3>Y4 THEN EXCHANGE Y3,Y4
394 10309 IF Y4>Y3 THEN 10393
395 10312 "
396 10315 '** THE MAX & MIN CANNOT BE EQUAL'
397 10318 RETURN

```

6-9

```

398 10321 LET Y1=Y2=Y3=Y4=0
399 10393 Y8=02
400 10417 REM ----- SORT ARRAYS -----
401 10420 IF Y8>25 AND Y1<0 AND Y2<Y1 THEN 10444
402 10423 FOR Y9=1 TO Y8
403 10426 FOR Y0=Y9 TO Y8
404 10429 IF X(Y9)<X(Y0) THEN 10438
405 10432 EXCHANGE X(Y9),X(Y0)
406 10435 EXCHANGE Y(Y9),Y(Y0)
407 10438 NEXT Y0
408 10441 NEXT Y9
409 10444 IF Y18='OVERLAY' THEN 10516
410 10447 IF Y1=0 AND Y2=0 AND Y3=0 AND Y4=0 THEN GOSUB 10483
411 10450 IF Y1<Y2 AND Y3<Y4 THEN 10508
412 10453 ' '
413 10456 '** THE DIFFERENCE BETWEEN THE LARGEST & SMALLEST VALUES IS TOO SMALL'
414 10459 PRINT ' X MIN='Y1
415 10462 PRINT ' X MAX='Y2
416 10465 PRINT ' Y MIN='Y3
417 10468 PRINT ' Y MAX='Y4
418 10471 ' '
419 10474 ' ERROR RETURN'
420 10477 ' '
421 10480 RETURN
422 10483 LET Y1=X(1)
423 10486 LET Y2=X(Y8)
424 10489 LET Y3=Y(1)
425 10492 LET Y4=Y(1)
426 10495 FOR Y9=1 TO Y8
427 10498 IF Y(Y9)<Y3 THEN LET Y3=Y(Y9)
428 10501 IF Y(Y9)>Y4 THEN LET Y4=Y(Y9)
429 10504 NEXT Y9
430 10507 RETURN
431 10508 LET Y1=Y1-(Y2-Y1)/59
432 10509 LET Y3=Y3-(Y4-Y3)/(X1-1)
433 10510 LET Y5=(Y2-Y1)/60
434 10513 LET Y6=(Y4-Y3)/X1
435 10516 IF Y18='OVERLAY' THEN LET Y1=Y1-(Y2-Y1)/59
436 10517 IF Y18='OVERLAY' THEN LET Y3=Y3-(Y4-Y3)/(X1-1)
437 10546 LET Y98='NO'
438 10549 LET X2=0
439 10552 FOR Y9=1 TO Y8
440 10555 IF X(Y9)<Y1 THEN 10717
441 10558 IF X(Y9)>Y2 AND Y8<=25 THEN 10720
442 10561 IF X(Y9)>Y2 THEN 10717
443 10564 IF X2=0 THEN 10588
444 10567 LET X0=INP((X(Y9)-Y1)/Y5+.5)
445 10570 LET Y0=INP((Y(Y9)-Y3)/Y6+.5)
446 10573 IF X0=0 OR Y0=0 THEN 10717
447 10576 IF Y0<1 OR Y0>X1 THEN 10687
448 10579 LET Z(X0,Y0)=Y7
449 10582 LET X2=Y9
450 10585 GO TO 10717
451 10588 LET X3=X(Y9)-X(X2)
452 10591 LET X4=ABS(Y(Y9)-Y(X2))
453 10594 IF X3<(Y5/2) AND X4<(Y6/2) THEN 10717
454 10597 LET X3=INP((X(Y9)-Y1)/Y5+.5)

```

6-10

```

453 10600 LET X4=INP((Y(Y9)-Y3)/Y6+.5)
454 10603 IF X4<1 OR X4>X1 THEN 10687
457 10606 IF X3=X0 AND X4=Y0 THEN 10717
458 10609 IF Z(X3,X4)=5 THEN LET Z(X3,X4)=Y7
459 10612 IF Z(X3,X4)=34 THEN LET Z(X3,X4)=Y7
460 10615 IF Y9='ND' THEN 10717
461 10618 IF X0<X3 THEN 10645
462 10621 REM --- THE X VALUE IS FIXED ---
463 10624 LET X8=Y0
464 10627 LET X9=X4
465 10630 IF X8>X9 THEN EXCHANGE X8,X9
466 10633 FOR X6=X8 TO X9
467 10636 IF Z(X0,X6)=5 THEN LET Z(X0,X6)=34
468 10639 NEXT X6
469 10642 GO TO 10708
470 10645 REM --- FIND THE SLOPE ---
471 10648 LET X5=X0
472 10651 LET X4=Y0
473 10654 LET X7=(X4-X6)/(X3-X5)
474 10657 IF X7>0 THEN LET X9=X7+.5 ELSE LET X9=ABS(X7-.5)
475 10660 LET X9=INP(X9)
476 10663 IF X9=0 THEN 10678
477 10666 FOR X8=1 TO X9
478 10669 IF X7>0 THEN LET X6=X6+1 ELSE LET X6=X6-1
479 10672 IF Z(X5,X6)=5 THEN LET Z(X5,X6)=34
480 10675 NEXT X8
481 10678 LET X5=X5+1
482 10681 IF Z(X5,X6)=5 THEN LET Z(X5,X6)=34
483 10684 IF X5<X3 THEN 10654 ELSE 10708
484 10687 IF Y0<1 OR X4<1 THEN LET X4=1 ELSE LET X4=X1
485 10690 IF X2>0 AND Z(X3,X4)<>5 AND Z(X3,X4)<>34 THEN 10708
486 10693 IF X2=0 AND Z(X0,X4)<>5 AND Z(X0,X4)<>34 THEN 10708
487 10696 IF X4=X1 THEN 10705
488 10699 IF X2=0 THEN LET Z(X0,X1)=7 ELSE LET Z(X3,X1)=7
489 10702 GO TO 10708
490 10705 IF X2=0 THEN LET Z(X0,X1)=6 ELSE LET Z(X3,X1)=6
491 10708 LET X0=X3
492 10711 LET Y0=X4
493 10714 LET X2=Y9
494 10717 NEXT Y9
495 10718 LET Y1=Y1+(Y2-Y1)/60
496 10719 LET Y3=Y3+(Y4-Y3)/X1
497 10720 IF F(7)=1 THEN RETURN
498 10721 PRINT ' '
499 10723 'HOME';
500 10726 INPUT Y7$
501 10729 IF Y3$='PLOTS' THEN 10750
502 10732 LET X$=Y3$
503 10735 LET X0=LEN(X$)
504 10738 LET Y0=INP((72-X0)/2+.5)
505 10741 PRINT TAB(Y0);
506 10744 PRINT X$
507 10747 GO TO 10753
508 10750 PRINT TAB(30);'PLOT 'Y20
509 10753 PRINT ' X'
510 10754 FOR X0=1 TO 5
511 10759 PRINT '-----';

```

6-11

```

312 10762 NEXT X0
313 10765 LET X$='
314 10768 LET Y$=Y5$
315 10771 LET Y0=LEN(Y$)
316 10774 LET X0=INP((X1-Y0)/2+.5)
317 10777 LET Y7$=ADDS(X$,Y$,X0)
318 10780 LET Y9=4
319 10783 FOR Y0=1 TO X1
320 10786 LET X$=Y$+' '
321 10789 FOR X0=1 TO 60
322 10792 LET X2=X1+1-Y0
323 10795 LET Y8=Z(X0,X2)
324 10798 LET X$=PUT$(Y$,X0,Y8)
325 10801 LET Y$=X$
326 10804 NEXT X0
327 10807 LET Y$=Y7$
328 10810 LET X0=GET(Y$,Y0)
329 10813 LET Y$=' '
330 10816 LET Y6$=PUT$(Y$,1,X0)
331 10819 PRINT Y6$;
332 10822 LET Y9=Y9+1
333 10825 IF Y9=5 THEN LET Y9=0
334 10828 IF Y0<>1 AND Y0<>X1 THEN 10840
335 10831 IF Y0=1 THEN LET Y8=Y4 ELSE LET Y8=Y3
336 10834 PRINT IN IMAGE '0.#####':Y8;
337 10837 GO TO 10849
338 10840 IF Y9<>0 THEN 10855
339 10843 LET X0=Y4-(Y0-1)*Y4
340 10846 PRINT IN IMAGE '0.#####':X0;
341 10849 PRINT '+';
342 10852 GO TO 10858
343 10855 PRINT ' '
344 10858 PRINT X$
345 10861 NEXT Y0
346 10864 PRINT ' '
347 10867 FOR X0=1 TO 5
348 10870 PRINT '-----';
349 10873 NEXT X0
350 10876 FOR X0=1 TO 4
351 10879 LET Y9=Y1+12*X0*Y5
352 10882 LET Y8=10+X0*12-4
353 10885 PRINT TAB(Y8);
354 10888 PRINT IN IMAGE '0.#####':Y9;
355 10891 NEXT X0
356 10894 ' '
357 10897 PRINT TAB(6);
358 10900 PRINT IN IMAGE '0.#####':Y1;
359 10903 PRINT TAB(63);
360 10906 PRINT IN IMAGE '0.#####':Y2
361 10909 LET X$=Y4$
362 10912 LET X0=LEN(X$)
363 10915 LET Y0=INP((72-X0)/2+.5)
364 10918 PRINT TAB(Y0);Y4$
365 10921 LET Y8$='NEW'
366 10924 ' '
367 10927 'NORMAL RETURN'
368 10930 RETURN

```


613

6-12

349	10933	' '
370	10934	'ESCAPE RETURN'
371	10939	RETURN

7-1

```

1 C *****
2 C *
3 C * SUBROUTINE SHOOTH *
4 C *
5 C * OPTIONS ARE *
6 C * 1) DO NOT SHOOTH ACROSS EMISSION/ABSORPTION BOUNDARY. *
7 C * 2) IN SMOOTHING, IGNORE EMISSION/ABSORPTION BOUNDARY. *
8 C *
9 C *****
10 18000 REM SUBROUTINE SHOOTH
11 18005 GOSUB 15930
12 18008 IF K5<1 AND K5>2 THEN 18200
13 18030 GOSUB 15900
14 18035 PRINT 'WILL BE SMOOTHED, USING A TRIANGULAR SMOOTHING FUNCTION.'
15 18040 GOSUB 22020
16 18045 PRINT 'THE UNSMOOTHED PROFILE IS STORED IN'
17 18050 K3==K4
18 18055 GOSUB 15900
19 18060 K3==K4
20 18065 FOR I=K1 TO K2 V(K4,I)=V(K3,I)
21 18070 K6=K2-K1
22 18075 IF K6=0 THEN 18215
23 18080 IF K1=M1 AND K5=1 THEN 18190
24 18085 IF K5=1 THEN 18100
25 18090 PRINT 'EMISSION-ABSORPTION BOUNDARY BEING IGNORED DUE TO '
26 18095 PRINT 'OPTION CHOICE.'
27 18100 V(K3,K1)=(V(K4,K1)+V(K4,K1+1))/2
28 18105 K1=K1+1
29 18110 IF K5=1 AND M1>K1 THEN K6=M1-1
30 18115 IF K5=2 THEN K6=K2-1
31 18120 IF K5=1 THEN IF M1>K2 OR M1<K1 THEN K6=K2-1
32 18125 IF K1>K6 THEN 18145
33 18130 FOR I=K1 TO K6
34 18135 V(K3,I)=(V(K4,I-1)+2*V(K4,I)+V(K4,I+1))/4
35 18140 NEXT I
36 18145 V(K3,K6+1)=(V(K4,K6)+V(K4,K6+1))/2
37 18150 IF (K6+1)=K2 THEN RETURN
38 18155 IF (K6+1)>K2 THEN 18225
39 18160 K1=M2+1
40 18165 K6=K2-1
41 18170 IF K1>K2 THEN RETURN
42 18175 IF K1=K2 THEN 18145
43 18180 V(K3,M2)=(V(K4,M2)+V(K4,K1))/2
44 18185 GO TO 18130
45 18190 IF K2>M2 THEN V(K3,M2)=(V(K4,M2)+V(K4,M2+1))/2
46 18195 GO TO 18160
47 18200 GO TO 22000
48 18215 PRINT 'ONE POINT ONLY: NO NET SMOOTHING EFFECT.'
49 18220 RETURN
50 18225 PRINT 'INDEX ERROR IN SMOOTHING ROUTINE.'
51 18230 PRINT 'CHECK THE LAST DATA POINTS MANUALLY.'
52 18235 GO TO 22005

```

8-1

```

1  C *****
2  C *
3  C * SUBROUTINE WANDER
4  C *
5  C * OPTIONS ARE
6  C * 1) RANDOM SPARK WANDER.
7  C * 2) CENTRALLY PEAKED WANDER.
8  C *
9  C *****
10 24100 REM SUBROUTINE WANDER
11 24105 GOSUB 15930
12 24110 IF K5<>1 AND K5<>2 THEN 22000
13 24115 IF K5=2 THEN 24160
14 24120 IF K3=K4 OR K3=170RK4=17 OR K3=13 OR K4=13 THEN 24125 ELSE 24135
15 24125 'INCOMPATIBLE PROFILE NUMBERS IN WANDER. RETURN AND TRY AGAIN.'
16 24130 RETURN
17 24135 PRINT 'SPARK WILL WANDER RANDOMLY.'
18 24140 PRINT 'HOW MANY SPARKS DO YOU WANT?';
19 24145 INPUT P1
20 24150 IF ABS(INT(P1))<>P1 OR P1>1000 OR P1<1 THEN 24140
21 24155 GO TO 24165
22 24160 PRINT 'WANDER WILL HAVE PEAKED DISTRIBUTION.'
23 24165 PRINT 'WHAT IS MAXIMUM ZONAL CHANNEL WANDER?';
24 24170 INPUT P2
25 24175 IF P2>50 OR ABS(INT(P2))<>P2 THEN 24165
26 24180 IF P2=0 THEN 24185 ELSE 24195
27 24185 PRINT 'STABLE SPARK. ROUTINE ABANDONED.'
28 24190 RETURN
29 24195 P5=K3
30 24200 P3=P4=0
31 24205 FOR I=K1 TO K2 V(17,I)=0
32 24210 P9=1.0
33 24215 P6=K3
34 24220 K3=K4
35 24225 K5=3
36 24230 K7=13
37 24235 ON P5 GO TO 24240,24255
38 24240 P3=INT(2*P2*(RND-.5)+.5)
39 24245 P4=P4+1
40 24250 GO TO 24270
41 24255 P3=P3+1
42 24260 P9=INT((P2/P3)**2)
43 24265 P4=P4+2*P9
44 24270 K4=P3
45 24275 FOR I=K1 TO K2 V(K4,I)=P9*V(P6,I)
46 24280 IF K4=0 THEN 24290
47 24285 GOSUB 14205
48 24290 FOR I=K1 TO K2 V(17,I)=V(17,I)+V(K4,I)
49 24295 IF P5=2 AND K6>0 THEN 24300 ELSE 24310
50 24300 K4=-K4
51 24305 GO TO 24275
52 24310 IF P5=1 AND P4=P1 THEN 24330 ELSE IF P5=2 AND P3=P2 THEN 24320
53 24315 GO TO 24335
54 24320 FOR I=K1 TO K2 V(17,I)=V(17,I)+V(P6,I)*(P2+1)**2
55 24325 P4=P4+(P2+1)**2
56 24330 FOR I=K1 TO K2 V(P6,I)=V(17,I)/P4
57 24335 PRINT P4: ' SPARKS FIRED: OUTPUT TO PROFILE' #P6

```

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8-2

58 24340 PRINT 'PREWANDER DATA IN PROFILE 13.'
59 24345 RETURN

Appendix A-3

DOCUMENTATION SUMMARY

This appendix, made up of the majority of the comment cards from the program listing, is a concise documentation of program ABEL3. While explanation is sparse, someone familiar with the program can use these pages as a run-time reminder of which subroutines, labels, etc. are available. It has been the author's experience that once the program is familiar, this is the only documentation that need regularly be consulted.

C-1

```

1 C *****
2 C *
3 C * PROGRAM ABEL3          WRITTEN IN BASIC
4 C * DOCUMENTED FOR PROGRAM VERSION OF JULY, 1977.
5 C *
6 C * PROGRAM ALLOWS MODELING OF THE OBSERVATION OF AN EMITTING OR
7 C * ABSORBING DISCHARGE WITH CYLINDRICAL SYMMETRY INCLUDED
8 C * PHENOMENA ARE: EMISSION, ABSORPTION WHICH IS SPATIALLY
9 C * FARTHER FROM THE SPARK AXIS THAN THE EMISSION, EMITTING
10 C * CONTINUUM BACKGROUND, SPARK WANDER, NOISE IN THE SIGNAL, AND
11 C * SMOOTHING OF THE SIGNAL. THE PROGRAM IS SO STRUCTURED AS TO
12 C * ALLOW ANYONE FAMILIAR WITH BASIC TO ADD HIS OWN IDEAS TO THOSE
13 C * ALREADY PROGRAMMED.
14 C *
15 C * PREPARED BY A. SCHEELINE UNDER THE DIRECTION OF:
16 C * PROF. JOHN P. WALTERS
17 C * DEPARTMENT OF CHEMISTRY
18 C * UNIVERSITY OF WISCONSIN
19 C * MADISON, WISCONSIN 53706
20 C *
21 C *****
22 C *****
23 C *
24 C * LINE NUMBER ASSIGNMENTS IN PROGRAM ABEL3
25 C * 0- 1000 DATA AND DIM STATEMENTS.
26 C * 1000- 1499 FIRST PASS INITIALIZATION.
27 C * 1500- 3000 PINWHEEL HUB: MAIN CONTROL ROUTINE.
28 C * 3000- 3500 GENERAL REINITIALIZATION ROUTINE.
29 C * 4000- 5000 SUBROUTINE CONSTRUC
30 C * 6000- 7000 SUBROUTINE FORWARD
31 C * 8000- 8900 SUBROUTINE PRINT-PLOT
32 C * 9000- 9999 PEPSUR (MODIFIED BY HARDWIRING OPTIONS).
33 C * 10000-10999 MINI-PLOT (MODIFIED BY HARDWIRING OPTIONS).
34 C * 11000-11500 EXECUTION TERMINATION ROUTINE.
35 C * 12000-13000 SUBROUTINE NOISE
36 C * 14000-15000 SUBROUTINE SHIFT
37 C * 15900-15920 PRINT PROFILE RELATED INFORMATION--SLAVE ROUTINE.
38 C * 15930-15960 INTERCONNECT CORE AND SUBROUTINES--SLAVE ROUTINE.
39 C * 16000-17000 SUBROUTINE ABEL
40 C * 18000-19000 SUBROUTINE SMOOTH
41 C * 22000-22100 SLAVE ERROR HANDLING ROUTINES.
42 C * 24000-25000 SUBROUTINE WANDER
43 C * -99999 END STATEMENT.
44 C *
45 C * ALL OTHER STATEMENT NUMBERS ARE AVAILABLE FOR
46 C * NEW AND DIFFERENT SUBROUTINES.
47 C *
48 C *****

```

C-2

```

49 C *****
50 C *
51 C * TABLE CORRELATING PROFILE NUMBERS AND MEANINGS:
52 C * 1) USER CONSTRUCTED RADIAL EMISSION PROFILE.
53 C * 2) USER CONSTRUCTED RADIAL ABSORPTION PROFILE.
54 C * 3) LATERAL INTENSITY PROFILE.
55 C * 4) BACKLIGHT PROFILE.
56 C * 5) CONSTRUCT SCRATCH REGISTER.
57 C * 6) EMISSION/ABSORPTION PROFILE CORRESPONDING TO 3) AND 4).
58 C * ASSUMES DREAMS MODEL.
59 C * 7) EMISSION PROFILE BASED ON EMISSION MODEL ONLY.
60 C * 8) USER CONSTRUCTED EMISSION/ABSORPTION RADIAL PROFILE.
61 C * 9) NOISE SCRATCH REGISTER.
62 C * 10) BACKGROUND INTENSITY DISTRIBUTION.
63 C * 11) BACKGROUND SPECIES DISTRIBUTION.
64 C * 12) SMOOTH SCRATCH REGISTER.
65 C * 13) SHIFT SCRATCH REGISTER (LATERAL INTENSITY PROFILE).
66 C * 14) SHIFT SCRATCH REGISTER (BACKGROUND INTENSITY PROFILE).
67 C * 15) ABSORPTION COMPENSATED INTENSITY PROFILE.
68 C * 16) WANDER SCRATCH REGISTER.
69 C * 17) WANDER ACCUMULATOR PROFILE.
70 C * 18) SCRATCH REGISTER A.
71 C * 19) SCRATCH REGISTER B.
72 C *
73 C *****
74 C *****
75 C *
76 C * TABLE OF FLAG MEANINGS
77 C * 1) LAST EMISSION ZONE NUMBER AS SET IN INITIALIZATION.
78 C * 2) ABSORPTION OR EMISSION PROFILE CONSTRUCTED--1=YES, 0=NO.
79 C * 3) BACKLIGHT PROFILE CONSTRUCTED--1=YES, 0=NO.
80 C * 4) TRANSMITTED INTENSITY CALCULATED SINCE BACKLIGHT PROFILE
81 C * CONSTRUCTED--1=NO, 0=YES.
82 C * 5) IF 4=NO, IS IT STILL OK TO DO THE INVERSION--1=YES, 0=NO.
83 C * 7) PLOT ENABLE FLAG--1=PLOT, 0=AWAIT NEXT PASS.
84 C * 8) SHOULD CONSTRUCT AUTOMATICALLY CREATE V(8,I) FROM V(1,I) AND
85 C * V(2,I)--1=NO, 0=YES.
86 C * 9) BATCH VS. TIMESHARE MODE. 1=BATCH, 0=TIMESHARE.
87 C * 6) AND 10) ARE CURRENTLY UNASSIGNED.
88 C *
89 C *****

```

C-3

```

90 C *****
91 C *
92 C * CONTROL ROUTINE SPECIFIES:
93 C *
94 C * 1) SUBROUTINE NUMBER.
95 C * 2) OPTION NUMBER WITHIN SUBROUTINE.
96 C * 3) MAJOR PROFILE AFFECTED.
97 C * 4) MINOR PROFILE AFFECTED.
98 C * 5) FIRST (INNER) ZONE OR RING AFFECTED.
99 C * 6) LAST (OUTER) ZONE OR RING AFFECTED.
100 C *
101 C * IN BATCH MODE, THESE ARE SPECIFIED AS 6 NUMBERS SEPARATED BY
102 C * COMMAS ON A SINGLE INPUT CARD. INTERACTIVELY, VALUES ARE
103 C * SUPPLIED IN RESPONSE TO A PROMPT. IN ADDITION, NONNUMERIC
104 C * VALUES WHICH MAY BE GIVEN IN CONJUNCTION WITH NUMERIC COMMANDS
105 C * ARE AS FOLLOWS:
106 C *
107 C * E ERROR-REASK QUESTION.
108 C * R RESTART CONTROL CALLING SEQUENCE; THROW OUT
109 C * CURRENT CONTROL VALUES.
110 C * S SHUT DOWN PROGRAM, SAVING APPROPRIATE OUTPUT FILES.
111 C * USE IN PLACE OF THE BASIC 'STOP' COMMAND.
112 C * USE OF 'STOP' WILL WIPE OUT PLOT INFORMATION AND
113 C * LEAVE YOU IN BASIC. IF NO PLOTS ARE GENERATED,
114 C * S LEAVES YOU IN BASIC ANYWAY. ALSO, IN BATCH MODE,
115 C * S LEAVES YOU IN BASIC.
116 C * T IDENTICAL IN USE TO S. S STANDS FOR STOP. T
117 C * STANDS FOR TERMINATE. USE EITHER OR BOTH.
118 C * D ON ALL SUBSEQUENT QUESTIONS REGARDING THIS
119 C * SUBROUTINE CALL, USE DEFAULT VALUES RATHER THAN
120 C * ASKING FOR INPUT.
121 C *
122 C * ALL OF THE ABOVE ALPHABETIC COMMANDS MAY BE USED ALONE EXCEPT D
123 C * WHICH MUST BE PRECEDED BY A NUMBER. SINCE 0 IS A UNIVERSAL
124 C * DEFAULT VALUE, ENTERING 0D WILL GIVE DEFAULT VALUES NOT ONLY
125 C * ON SUBSEQUENT QUESTIONS BUT ON THE CURRENT QUESTION AS WELL.
126 C * THE LETTERS ARE SEARCHED FOR AND HAVE EFFECT IN THE ORDER SHOWN.
127 C *
128 C *****

```


C-4

```

129 C *****
130 C *
131 C * SUBROUTINES AND DEFAULT VALUES ARE:
132 C *
133 C * SUBROUTINE          DEFAULT VALUES
134 C * NAME      NUMBER  OPTION  MAJOR PROFILE  MINOR PROFILE
135 C * CONSTRU  1         4        1          11
136 C * FORWARD  2         1        8           2
137 C * NOISE    3         2        3           9
138 C * SHIFT    4         4        3          10
139 C * ABEL     5         1        3           4
140 C * PRINT-PLOT 6       11       4           1
141 C * SHOOTH   7         1        3          12
142 C * WANDER   8         1        3          14
143 C *
144 C * LEGAL ANSWERS TO 'WHICH OPTION' AND WHAT THEY MEAN.
145 C * POSITIVE INTEGERS      VALUE DIRECTLY ASSIGNED AS OPTION FOR
146 C *                          THIS CALL TO THIS SUBROUTINE.
147 C * 0                        USE DEFAULT OPTION.
148 C * -1                       LEAVE OPTION UNCHANGED FROM PREVIOUS CALL
149 C *                          TO THIS SUBROUTINE. THIS CHOICE IS RIFE
150 C *                          WITH OPPORTUNITIES FOR ERRORS; ITS USE
151 C *                          IS NOT RECOMMENDED.
152 C * -2                       CHANGE THE DEFAULT OPTION FOR THIS
153 C *                          SUBROUTINE; THE NEW DEFAULT OPTION IS
154 C *                          IN EFFECT IF THE SUBROUTINE IS IN FACT
155 C *                          ALLOWED TO EXECUTE DURING THIS CALL.
156 C *
157 C * LEGAL VALUES FOR PROFILE NUMBERS AND WHAT THEY MEAN.
158 C * INSTRUCTIONS HERE ARE THE SAME AS IN THE SECTION JUST CONCLUDED
159 C * ON ASSIGNING OPTION VALUES, EXCEPT THAT THE WORDS 'PROFILE
160 C * NUMBER' SHOULD BE SUBSTITUTED FOR THE WORD 'OPTION' ABOVE.
161 C *
162 C * LEGAL RING AND ZONE NUMBER ASSIGNMENTS.
163 C * POSITIVE INTEGERS      VALUES BETWEEN 1 AND 50 ARE USED TO
164 C *                          INDICATE LIMITS DIRECTLY. DEFAULT
165 C *                          ASSIGNMENT OVERRIDES DIRECT ASSIGNMENT.
166 C * 0                        ALL ZONES AND RINGS 1 THROUGH 50 ARE
167 C *                          OPERATED ON BY THE SUBROUTINE.
168 C * -1                       ONLY ZONES OR RINGS IN THE EMISSION REGION*
169 C *                          ARE OPERATED ON BY THE SUBROUTINE.
170 C * -2                       ONLY RINGS AND ZONES IN THE ABSORPTION
171 C *                          REGION ARE OPERATED ON BY THE SUBROUTINE.
172 C *
173 C *****

```

C-5

```

174 C *****
175 C *
176 C * SUBROUTINE CONSTRUCT
177 C *
178 C * OPTIONS ARE
179 C * 1) ADD ON-AXIS GAUSSIAN PROFILE TO PRESENT PROFILE.
180 C * 2) ADD OFF-AXIS GAUSSIAN PROFILE TO PRESENT PROFILE.
181 C * 3) ADD ELLIPSOIDAL PROFILE TO PRESENT PROFILE.
182 C * 4) ADD HOMOGENEOUS (CONSTANT IN EACH RING OR ZONE) PROFILE
183 C * TO PRESENT PROFILE.
184 C * 5) INPUT DIRECTLY VALUES IN A FEW ZONES OR RINGS.
185 C * 6) INPUT DIRECTLY VALUES FOR ALL POSSIBLE (BASED ON LOOP
186 C * INDICES CHOSEN) ZONES OR RINGS.
187 C * 7) SCALE THE VALUES IN A FEW ZONES OR RINGS.
188 C * 8) SCALE ALL POSSIBLE ZONES OR RINGS.
189 C * 9) ADD INPUT VALUES TO THE PRESENT VALUE OF A FEW ZONES OR RINGS*
190 C * 10) ADD INPUT VALUE TO PRESENT PROFILE VALUE IN ALL POSSIBLE
191 C * RINGS OR ZONES.
192 C * 11) ADD MINOR PROFILE TO MAJOR PROFILE; STORE IN MAJOR PROFILE.
193 C * 12) SUBTRACT MINOR PROFILE FROM MAJOR PROFILE; STORE IN MAJOR
194 C * PROFILE.
195 C * 13) SCALE ALL VALUES BY AN INPUT CONSTANT.
196 C * 14) CROSS-MULTIPLY THE INPUT PROFILES; STORE IN MAJOR PROFILE.
197 C * BY ADDING 20 TO ANY OF THE ABOVE OPTIONS, THE OPTION
198 C * WILL BE EXECUTED AFTER THE APPLICABLE SECTION OF THE PROFILE
199 C * HAS BEEN CLEARED.
200 C * PERMANENT SCRATCH REGISTER FOR THIS ROUTINE IS V(5,I).
201 C *
202 C *****

```

C-6

```

203 C *****
204 C *
205 C * SUBROUTINE FORWARD
206 C *
207 C * OPTIONS ARE:
208 C * 1) USING THE MAJOR PROFILE AS A RADIAL EMISSION PROFILE AND
209 C * THE MINOR PROFILE AS THE RADIAL ABSORPTION PROFILE, COMPUTE
210 C * A LATERAL INTENSITY PROFILE AND STORE IT IN PROFILE #3.
211 C * PROFILE 4 IS USED AS THE BACKLIGHT PROFILE, AND THE
212 C * EMISSION/ABSORPTION BOUNDARY AS SET IN INITIALIZATION IS
213 C * USED. IF THE MAJOR PROFILE IS PROFILE 8, THEN THE MINOR
214 C * PROFILE IS AUTOMATICALLY ASSUMED TO BE 8, OVERRIDING THE
215 C * CHOICE MADE IN THE CALLING SEQUENCE.
216 C * 2) CONVERT THE MAJOR PROFILE INTO A LATERAL INTENSITY
217 C * PROFILE, IGNORING ABSORPTION. ABSORBING REGIONS OF THE
218 C * INPUT AND OUTPUT PROFILES ARE IGNORED.
219 C * 3) CONVERT THE MAJOR PROFILE INTO A LATERAL INTENSITY
220 C * (TRANSMITTANCE) PROFILE, ASSUMING ONLY ABSORPTION TAKES
221 C * PLACE. EMISSION REGION OF INPUT AND OUTPUT PROFILES ARE
222 C * NOT AFFECTED.
223 C * 4) INSTALL RADIAL ABSORBER AS DESCRIBED IN THE MINOR PROFILE
224 C * AROUND THE LATERAL INTENSITY DATA IN THE MAJOR PROFILE.
225 C * RESULTS STORED IN THE MAJOR PROFILE, AND A TRANSMITTANCE
226 C * PROFILE IS NOT GENERATED IN THE ABSORBING REGION.
227 C *
228 C * ADDING 10 TO OPTION 2 OR 3 MAKES FORWARD IGNORE THE
229 C * ARBITRARY EMISSION/ABSORPTION BOUNDARY SET DURING INITIALIZATION.
230 C * THUS ZONES AND RINGS EXCLUDED FROM TREATMENT IN OPTIONS 2 AND 3
231 C * ARE TREATED IN OPTIONS 12 AND 13.
232 C *
233 C * RESULTS AUTOMATICALLY STORED IN PROFILE 3 EXCEPT WHEN OPTION 4
234 C * IS USED.
235 C *
236 C *****
237 C *****
238 C *
239 C * SUBROUTINE NOISE
240 C *
241 C * OPTIONS ARE:
242 C * 1) ADD NOISE INDEPENDENT OF THE VALUE OF THE INPUT NOISELESS
243 C * DATA.
244 C * 2) ADD NOISE BASED ON THE MAXIMUM DATA VALUE IN THE EMISSION
245 C * REGION OF THE INPUT DATA PROFILE.
246 C * 3) ADD NOISE BASED ON THE MAXIMUM VALUE IN THE ABSORPTION
247 C * REGION OF THE INPUT DATA PROFILE.
248 C * 4) ADD NOISE PROPORTIONAL TO THE NOISELESS DATUM VALUE.
249 C * 14) ADD NOISE PROPORTIONAL TO THE SQUARE ROOT OF THE NOISELESS
250 C * DATUM VALUE.
251 C * 24) ADD NOISE WHICH IS PROPORTIONAL TO AN ARBITRARY POWER OF THE
252 C * NOISELESS DATUM VALUES.
253 C *
254 C *****

```

C-7

```

255 C *****
256 C *
257 C * SUBROUTINE SHIFT
258 C *
259 C * OPTIONS ARE
260 C * 1) SHIFT MAJOR PROFILE. EMISSION/ABSORPTION BOUNDARY FIXED.
261 C * REFLECT AND FILL TO COMPLETE PROFILE AS NECESSARY.
262 C * 2) SAME AS 1) EXCEPT THAT EMISSION/ABSORPTION BOUNDARY IS SHIFTED*
263 C * IN THE SAME MANNER AS THE PROFILE.
264 C * 3) SAME AS 1) EXCEPT THAT EMISSION/ABSORPTION BOUNDARY IS
265 C * IGNORED COMPLETELY.
266 C * 4) UNSHIFT PROFILE CURRENTLY IN STORAGE AND PLACE IT IN THE
267 C * MAJOR PROFILE.
268 C * 5) REINITIALIZE SYSTEM.
269 C * 6) RESET EMISSION/ABSORPTION BOUNDARY.
270 C *
271 C * ADDING 10 TO OPTIONS 1 THROUGH 3 CANCELS REFLECTION AND FILLING.
272 C * PROFILES OTHER THAN THOSE SPECIFIED IN THE SUBROUTINE CALL MAY DE*
273 C * SHIFTED UNDER SPECIAL CIRCUMSTANCES, DESCRIBED FULLY IN THE
274 C * FULL PROGRAM DOCUMENTATION.
275 C *
276 C *****
277 C *****
278 C *
279 C * SUBROUTINE ABEL
280 C *
281 C * OPTION ARE
282 C * 1) PERFORM ABEL INVERSION TAKING EMISSION/ABSORPTION BOUNDARY
283 C * AS CORRECT. GIVES PROPER DREAMS MODEL INVERSION.
284 C * 2) INVERT MAJOR PROFILE ASSUMING A TOTALLY EMITTING PROFILE.
285 C * 3) INVERT MAJOR PROFILE ASSUMING A TOTALLY ABSORBING PROFILE.
286 C * 4) TAKE EMISSION INTENSITY FROM MAJOR PROFILE AND ABSORBING
287 C * SPECIES DISTRIBUTION FROM MINOR PROFILE. PERFORM LATERAL
288 C * TO RADIAL INVERSION ON EMISSION INTENSITY DATA.
289 C *
290 C * OUTPUT IS TO PROFILE 6 EXCEPT IF OPTION 2 IS CHOSEN;
291 C * IN THAT CASE, OUTPUT MAY BE DIRECTED TO EITHER PROFILE 6 OR 7,
292 C * WITH THE CHOICE BEING MADE WITHIN THE SUBROUTINE, NOT IN THE
293 C * CONTROL ROUTINE.
294 C *
295 C *****

```

C-8

```

294 C *****
295 C *
296 C * SUBROUTINE PRINT-PLOT
297 C *
298 C *
299 C * OPTIONS ARE
300 C *
301 C * 1) PLOT USING DEAN STUELAND'S MINI-PLOT ROUTINE (WITH OPTIONS
302 C *    HARDWIRED).
303 C * 2) PLOT USING DEAN STUELAND'S PEPSUB ROUTINE (WITH MOST OPTIONS
304 C *    HARDWIRED).
305 C * 3) PLOT USING FIRST MINI-PLOT AND THEN PEPSUB.
306 C * 10) PRINT A LISTING OF THE CONTENTS OF THE MAJOR PROFILE AND
307 C *    THE BASE 10 LOG OF SAID DATA.
308 C * 11) THROUGH 13) COMBINE OPTION 10 WITH OPTIONS 1 THROUGH 3
309 C *    RESPECTIVELY.
310 C *
311 C * ALL OPERATIONS USE ONLY THE MAJOR PROFILE. THE MINOR PROFILE
312 C *    IS IRRELEVANT.
313 C *
314 C *****
315 C *****
316 C *
317 C * SUBROUTINE SHOOOTH
318 C *
319 C * OPTIONS ARE
320 C * 1) DO NOT SHOOOTH ACROSS EMISSION/ABSORPTION BOUNDARY.
321 C * 2) IN SHOOOTHING, IGNORE EMISSION/ABSORPTION BOUNDARY.
322 C *
323 C *****
324 C *****
325 C *
326 C * SUBROUTINE WANDER
327 C *
328 C * OPTIONS ARE
329 C * 1) RANDOM SPARK WANDER.
330 C * 2) CENTRALLY PEAKED WANDER.
331 C *
332 C *****

```

Appendix A-4

USE OF ABEL3 AT THE TELETYPE

Explicit procedures have been outlined for use of ABEL3 at a PEP terminal or in batch runs. In some cases it may be desirable to use a teletype or DECWRITER to run the program, which presents some inconveniences. These problems could be solved with minor program modifications, but here suggestions will be given for using the program as it currently is written.

If no plotting is done using PEPSUB, either "batch" or "time" mode may be used in executing the program. If, however, PEPSUB is used, a complication may arise.

- (a) If "batch" mode is used, no attempt is made to plot on the teletype, but the full core routine command set is not available. Thus, no problem arises in obtaining plot (the normal "batch" mode sequence may be used) but interaction may be inconvenient, particularly to a new user.
- (b) If "time" mode is used, interaction is detailed, but upon termination (S or T command), an attempt is made

to plot on the teletype, resulting in an unintelligible jumble being printed at the teletype. To avoid this, the following is recommended.

- (1) Run the program in "time" mode until, as previously described, it would be appropriate to enter the "S" or "T" command in the core routine.
- (2) Instead of entering S or T, call up subroutine number 6, option 2, major profile 1 (or any other profile--this is a dummy argument in this case), minor profile 0 (again, any profile is okay), first ring or zone -1 (to avoid the plot option questions).
- (3) In response to

D) PLOT STATUS?

Answer "CLOSE". That five letter word must be used. Specifically, do NOT use "New", "Overlay", "Done", or "Last".

- (4) Upon return to the core routine, and in direct contravention to all other comments on terminating the program, type the word STOP. Because steps (2) and (3) have been executed, the plot file is preserved.
- (5) Sign off the teletype with BYE and @FIN.
- (6) Go to a PEP terminal as would normally be done following a "BATCH" run to obtain the plot

```
(@RUN  
@PASS  
@ASG,A PLOT.  
@ADD,P PLOT.  
YES  
.  
YES  
@FIN)
```

- (7) If the PEP run is not to be performed on the same day as the teletype run, then after saying BYE and before saying @FIN in the teletype run, enter the statement

@SAVE,S PLOT.

After performing the PEP run to obtain plot, i.e. after entering the last YES and before saying @FIN, enter the statement

@DELETE PLOT.

Appendix A-5

EXAMPLE RUN OF PROGRAM ABEL3

On pages E1 through E28 appears a listing of the interactions which took place during a sample run of program ABEL3 and the output which resulted. The MACC supported processor BFNLIST in combination with appropriate @TTY commands was used to produce the hard copy of the run, which was conducted at a PEP terminal. Description of the use of BFNLIST is beyond the scope of this documentation, but may be found in the MACC Handbook.

Two distinct tasks were performed in this run: (1) the plots shown in Scheeline and Walters, Anal. Chim. Acta Comp. and Opt. Tech., 1, 59 (1977), Figure 6 were recreated and (2) a few manipulations involving both emitting and absorbing species were performed to demonstrate how this may be accomplished. A few extra steps are included to show as much as possible of the program's use.

Between line 4, page E-1 and line 1161, page E-21, the listing is an exact duplicate of the interactions which took place. Each line is numbered for easy reference, and labeled

with an "I" or "O" to signify Input by the user or Output by the computer. For lines numbered less than four or greater than 1161, proper interaction will be listed here, as BFNLIST precluded normal operation at these points, as did a temporary bug in the BASIC interpreter.

At the PEP terminal, line 5 would be reached as follows, using BFNLIST conventions for showing input and output: dial 31250; press DATA button on phone when "beep" is heard

```

I   UWGT
O   MACC 33.15 U02017
I   @RUN AS,41000,1893602639,$10.00
O   RUNIDY02345 DATE 07:25:77 TIME 20:30:30
O   PASSWORD PLEASE
O   *****
I   WORD
O   CONTINUE
I   @LIB*BACKUP.BASIC CHEMISTRY*WALTERS.
O   UBASIC 4.0.4 20:30:45 25 JUL 77

```

This sequence calls up the 1110, starts a run (@RUN statement), enters a password which authorizes an individual to use the computer (in this case, the password is "word"), and the BASIC processor is started. As program ABEL3 was earlier placed in file CHEMISTRY*WALTERS, that file is called up with BASIC.

At this point, only line numbers will be used instead of writing out the commands. After BASIC is called, a carat is output in line 4 and the program called up and started by lines 5-7. The program is initialized in lines 8-25 inclusive.

Interaction format is set up by the first question (lines 8-10). The random number (noise) generator is initialized so that the first pseudorandom number available in the noise routine is the first of a standard, documentable sequence. That is, every run initialized as in lines 11-15 will utilize the identical sequence of random numbers. The physical width of a ring or zone in the modeled discharge is set to 50 μm in lines 16-17.

This is a 50 ring/zone discharge model. Lines 18-19 specify that all 50 of these zones and rings can emit but not absorb light. Questions and answers in lines 20-25 are most relevant when absorption is considered and so are of little concern here--the answers shown in lines 23 and 25 are recommended for pure emission modeling.

Lines 27 through 41 constitute the first use of the hub of the program pinwheel. Lines 27 and 28 choose subroutine 1, the profile construction subroutine, for first execution. Lines 29 and 30 specify that option 2, the addition of an off-axis Gaussian profile to the data already present (all zeroes as this is the start of execution) should be performed. Lines 31 and 32 specify that the results of subroutine execution are to be stored in profile 1, the "user constructed radial emission profile".

As the minor profile is not used in this option, the remainder of the first core routine call (lines 33-37) was so

set that two optional features of the core routine are demonstrated. Note the input in line 34. The suffix "D" indicates that default values for all remaining core questions are to be assumed. As the only subsequent questions would concern the maximum and minimum zone limits to be affected by the subroutine, the D has the effect of allowing (forcing) operations to encompass all 50 rings in the affected profile. "-2" is the value chosen for the minor profile. That is, a new default value (replacing the original default minor profile for subroutine 4, which was profile 11, the Background Series Distribution) for the subroutine 1 minor profile is to be input, and this new value used on this execution of the subroutine in addition to future default minor profile assignments. In line 37, profile 18, the A scratch register, is chosen as the default minor profile.

Lines 39 through 41 summarize the parameters chosen in the core routine. Subroutine 1 starts to execute. Lines 42 through 50 enter the parameters describing the profile being constructed, an off-axis Gaussian radial emission profile. Because line 25 was answered "yes", both profiles 1 and 8 contain the calculated information.

In line 52, the core routine again executes. Here the output routine is called up to print and plot the profile just constructed. In line 57, after profile 1 is chosen for output, defaults are again chosen for minor profile and ring boundaries.

Line 62 is used so that a screen clear can be given (not output by BFNLIST) at the PEP terminal before a particular output item is listed or plotted. Here, the table of emission values was started at the top of a new page.

Lines 65-118 lists, with the rings and zones numbered under the "index" column the profile requested in the core routine. Both the data and base 10 logarithm of the data are given, with appropriate headings. Both the profile number and title are given for ready reference.

Lines 120-162 shows full execution of the "Miniplot" plotter routine which plots the data just listed. By clearing the screen using the "Home" capability (i.e. entering CTRL-O before typing and inputting "I" or some other character) the plot just fits on the PEP screen. Throughout this example are plots which were split on the line printer--they were not split on the PEP screen.

Lines 163 to 170 relates to the first running of PEPSUB. The interaction in lines 163-4 occurs only on this first call. The plot made using this call, after post-processing described later, produced the plot on page E-22.

This is a logical breaking point in program execution. One calculation has been performed (profile construction) and the results output.

The next operation is to convert the radial profile just calculated into a lateral, i.e. simulated observable profile. Along with output of the result, this takes lines 173 through 317. Specific items to note:

- (1) The core routine was executed with explicit answers to all questions (lines 173-184).
- (2) A full description of the operation of subroutine FORWARD is given in lines 186-198. Lines 189-190 are produced even though no absorption is modelable based on the initialization parameters. This is due to a flag which forces backlight profile construction on the first call to subroutine FORWARD which could conceivably involve a backlight if the user has not constructed such a profile first. This relieves the user of having to construct a specific profile unless desired, and prevents taking the logarithm of zero or infinity. Lines 193 and 194 are also generated due to the option choice even though no absorption region exists.
- (3) Subroutine FORWARD always puts the results of calculations into profile 3.
- (4) The hard copy plot for this PEPSUB call may be found on page E-23.

The goal of this section of the example run was to observe the effects of wander-on radial and lateral profiles. So the next step in execution is to call up the wander modeling routine, subroutine 8. As shown in line 325, the input data is all 50 zones of lateral intensity data in profile 3. Line 323 specifies random wander. Lines 331 to 334 specify how much wander is to take place (± 15 zones) and how many sparks are to be used (so that adequate statistics can occur). As the "sparks" could be centered in any of 31 zones and experience showed that six sparks per zone gave reasonable results, 200 sparks were chosen here ($6 \times 31 = 186$; 200 is the closest convenient round number. Obviously this choice of number of sparks was somewhat arbitrary and should not be regarded as a constraint by the user). If the data used as input to the wander routine is desired, it is in profile 13 (line 336); output is to the original input and major profile, number 3. Line 335 is a diagnostic which is merely confirmatory when option 1 is executed. If option 2 is chosen, this is the only convenient way to determine the number of discharges "fired".

Output (lines 338-461) of the lateral profile produced in the wander calculation contains few points not previously covered. Line 345 shows the use of "0" in the core routine to specify a default value for a single question (0D specifies default for both the given question and succeeding questions; nD where n is

an integer >0 specifies response n for the given question and defaults for succeeding questions). The hard copy line plot is on page E-24.

The last calculation step in the wander modeling is to reconvert the lateral data (profile 3 just output) to radial data to see how much blurring of chemical information has occurred due to wander. Lines 462 to 478 show the performance of this conversion using subroutine ABEL. Again, as in FORWARD, printouts relative to absorption are in fact functionless due to the lack of any absorption region. In line 477 "DREAMS" stands for "Decoupled Region Emission Absorption Model of the Spark", i.e. that both emission and absorption occur, but in spatially segregated regions. Output is as usual (lines 480 through 498); notice the vertical scale on the plot for comparison with the next section. Hard copy corresponding to this plot is on page E-25.

Lines 600 to 720 illustrate the construction and use of overlaid plots. Here, the original and wander-affected radial profiles are overlaid. The original profile is output first as this curve takes the largest range of ordinates and thus must be used for setting the vertical scale. Hard copy appears on page E-26. This plot should be compared to plots on pages E-22 and E-25, which were made using the same numerical data.

Line 720 concludes the wander modeling section of the sample run. It is now desired to illustrate some features of modeling a discharge which includes among its properties self-absorption. This necessitates reinitialization. Lines 722-725 call up the reinitializing option of subroutine SHIFT. Profile numbers and zone/ring number specifications are irrelevant as all zones and rings in all profiles are re-zeroed. By comparing lines 732 to 471 with lines 8 to 25, it may be noted that the only questions asked upon start up which are not asked upon reinitialization concern batch versus timesharing mode and the random number generator. Thus the internal state of the program is identical at line 741 to its state at 25, save for any use of the random number sequence and the existence on file of data plotable on the Calcomp plotter as output by PEPSUB. There is a caveat, however: The default minor profile (as reset for subroutine I in line 37) is not affected by initialization. If, as desired here, the previous resetting is to be cancelled, it must be done manually as in lines 751-753.

Since the emission/absorption boundary was set to ring and zone 25, the outer 25 rings and zones are now useable for modeling self-absorption. Thus both profiles 1 and 2 will be used in setting up the system to be modeled (radial emission and radial absorption profiles respectively). Profile 1 is constructed as an off-axis Gaussian in lines 760 to 768. Note the selection of

emission rings only in lines 754-755. The defaults 0 = all zones, -1 = emission zones only, -2 = absorption zones only are convenient, especially if the position of the boundary between emission and absorption is changed frequently. The construction of profile 2 in lines 770-792 follows a parallel course. Lines 758 and 782 confirm which rings are affected.

Lines 740-741 specified that a profile combining emission data from rings 1-25 of profile 1 and rings 26-50 of profile 2 be assembled in profile 8 each time either profile is changed by subroutine 1. Thus to output all the useful radial information at once, lines 798-799 specify outputting of profile 8. Compare the parameters entered in lines 762-768 and 787-792 with the tabular data in lines 809-862 and with the plot of these data at the bottom of page E-16. As there is now an absorption region, the interaction in lines 863-869 is added to the plot output routine. If "no" had been entered in line 865, all the symbols at the data points would have been the same. By answering "no" in line 869, the absorption side of the plot is independently scaled; reference to the tabular data reveals that the absorption data has a maximum value of five compared to a maximum of 1000 for the emission data. Had the default response ("0" or "-2") or "yes" been entered in 869, the absorption region data would all have appeared as "0" on the scale of the graph. The hard copy of this plot is on page E-27.

Just as a reminder, when "D) Plot Status?" is asked in line 871, it refers to the instant plot displayed on page E-16. When the question is asked in line 916, it refers to the PEPSUB plot for later hard copy production.

Once more, subroutine FORWARD is now called. The emission region data is converted to intensity as would be viewed in the lab after the emitted light passes through the absorbing layer, and the absorption region data is converted to intensity data reflecting the amount of backlight radiation allowed to pass to the point of observation. In this case, since the backlight is uniform with 100 units of intensity, the light seen in any zone which views only the absorption region may be viewed directly as percent transmittance. This may be seen in the listed data, listed 985-1009.

In the plot options for the output of FORWARD, the scaling option was intentionally misstated (line 1017), and the plot on page E-19 resulted. This was not thought useful for a hard copy plot; note the response in PEPSUB input in line 1065. The output routine is again called, this time specifying that no list of data be given (line 1073), and the correct plot specification is given (lines 1080-1086). The plot appears on page E-20, with the hard copy equivalent on page E-28.

The rest of the example run, on page E-21, was performed to illustrate some more features of the core control routine.

Lines 1140-1142: Effect of trying to use an undefined subroutine (only routines 1-8 are allowed).

Lines 1143-1146: After typing "7" in line 1144 it was decided that that was erroneous. By also typing "E" before hitting the carriage return, the "7" is ignored and the question reasked (in this case "7" was entered anyway in line 1146, but that in general would not be the response).

Lines 1149-1152: The R option Restarts asking of the core routine questions, going back to requesting the subroutine number.

In line 1153, the program is terminated in proper fashion (always terminate using a T or S command in the core routine, NEVER with the word "stop", or else all plot will be lost). Lines 1154 through 1161 (except for 1159 which is a quirk of BFNLIST) then appear automatically on the screen. Ignore the last three lines on page E-21; these were necessary to get the listing used on page E-1 to E-21 but are not part of the normal runstream. Further questions are asked to generate hard copy plot--simply answer all of them "yes" and plot will be produced on the PEP and Calcomp plotters. At the end, recheck the run I.D. number so that the hard copy plot may be obtained in the basement of MACC.

To finish the run, type

@FIN,C

and a billing for the run will be output.

To review the plots or view any plot whatsoever generated in a batch run, a separate run would be performed as follows:

Sign on as described at the beginning of this example, starting with dialing 3-1250 through entering the password and receiving the reply CONTINUE. The rest of the run would be:

```
I  @ASG,A PLOT.  
O  READY  
I  @ADD,P PLOT.
```

(enough "YES" commands to answer all ensuing questions--
copy run I.D. number at end.)

```
I  @FIN,C
```

E-5

227 0	10	.63808442	-.19512186
228 0	11	.66954294	-.17422156
229 0	12	.70585003	-.15128756
230 0	13	.74545847	-.12757655
231 0	14	.7853536	-.10493476
232 0	15	.82094297	-.08567644
233 0	16	.84442841	-.07237899
234 0	17	.85573505	-.06766068
235 0	18	.84333993	-.07399734
236 0	19	.80610994	-.09360573
237 0	20	.74405946	-.12839236
238 0	21	.6607484	-.17695073
239 0	22	.56287549	-.24956766
240 0	23	.45681503	-.33836237
241 0	24	.3571674	-.44712818
242 0	25	.26511157	-.57657132
243 0	26	.18739412	-.72724404
244 0	27	.1260107	-.89959257
245 0	28	.08054176	-1.0929789
246 0	29	.04889918	-1.3106984
247 0	30	.02818422	-1.549994
248 0	31	.01541465	-1.8120663
249 0	32	.00799683	-2.0970824
250 0	33	.00393385	-2.4051826
251 0	34	.00183449	-2.736485
252 0	35	.00081079	-3.0910903
253 0	36	.00033956	-3.4690845
254 0	37	.00013473	-3.8705414
255 0	38	5.0637779E-05	-4.2955253
256 0	39	1.8028365E-05	-4.7440912
257 0	40	6.0772932E-06	-5.2162898
258 0	41	1.9401616E-06	-5.7121621
259 0	42	5.8648012E-07	-6.2317467
260 0	43	1.6785038E-07	-6.7750776
261 0	44	4.5479302E-08	-7.3421862
262 0	45	1.1665275E-08	-7.9331049
263 0	46	2.8321433E-09	-8.5478846
264 0	47	6.5060027E-10	-9.1866856
265 0	48	1.4115436E-10	-9.8503057
266 0	49	2.8589692E-11	-10.54379
267 0	50	4.836056E-12	-11.315508
268 0			
269 0			
270 0	D) PLOT STATUS?		
271 0	NEW		
272 0			
273 0	HOME?		
274 0			
275 0			
276 0			
277 0	8.6E-01		
278 0			
279 0			
280 0			
281 0			
282 0	7.1E-01		
283 0			

LATERAL INTENSITY PROFILE

X

E-6

```

284 0 0 2
285 0 0 2
286 0 0 2
287 0 0 5.6E-01+
288 0 0 2
289 0 0 2
290 0 0 2
291 0 0 2
292 0 0 4.1E-01+
293 0 0 2
294 0 0 2
295 0 0 2
296 0 0 2
297 0 0 2.7E-01+
298 0 0 2
299 0 0 2
300 0 0 2
301 0 0 2
302 0 0 1.2E-01+
303 0 0 2
304 0 0 2
305 0 0 2
306 0 0 -2.3E-10+
307 0 0 2
308 0 0 1.0E+00 1.1E+01 2.1E+01 3.1E+01 4.1E+01 5.0E+01
309 0 0 1.0E+00 1.1E+01 2.1E+01 3.1E+01 4.1E+01 5.0E+01
310 0 0 ZONE-NUMBER
311 0 0
312 0 0 NORMAL RETURN
313 0 0
314 0 0 PLOT STATUS?
315 0 0 NEW
316 0 0
317 0 0 NORMAL RETURN
318 0 0
319 0 0
320 0 0 SUBROUTINE NUMBER=?
321 0 0 8
322 0 0 WHICH OPTION?
323 0 0 1
324 0 0 MAJOR PROFILE INVOLVED=?
325 0 0 16
326 0 0
327 0 0 IN SUBROUTINE WANDER OPTION 1 WILL BE
328 0 0 PERFORMED ON RINGS OR ZONES 1 TO 50
329 0 0 PROFILE NUMBERS= 3 16
330 0 0 SPARK WILL WANDER RANDOMLY.
331 0 0 HOW MANY SPARKS DO YOU WANT?
332 0 0 200
333 0 0 WHAT IS MAXIMUM ZONAL CHANNEL WANDER?
334 0 0 15
335 0 0 200 SPARKS FIRED; OUTPUT TO PROFILE 3
336 0 0 PREWANDER DATA IN PROFILE 13.
337 0 0
338 0 0 SUBROUTINE NUMBER=?
339 0 0 4
340 0 0 WHICH OPTION?

```

E-7

```

341 I 13
342 O MAJOR PROFILE INVOLVED=?
343 I 1
344 O SECONDARY PROFILE INVOLVED=?
345 I 0
346 O FIRST ZONE OR RING NUMBER=?
347 I 1
348 O LAST (OUTER) ZONE OR RING NUMBER=?
349 I 50
350 O
351 O IN SUBROUTINE PRINT-PLOT OPTION 13 WILL BE
352 O PERFORMED ON RINGS OR ZONES 1 TO 50
353 O PROFILE NUMBERS=      3      1
354 O NONE?
355 I 1
356 O
357 O PROFILE 3 , THE LATERAL INTENSITY PROFILE IS PRINTED BELOW.
358 O
359 O      INDEX      OBSERVED INTENSITY      LOG V(I,J)
360 O      1      .61594804      -.21045592
361 O      2      .61793242      -.20905902
362 O      3      .62168247      -.20643138
363 O      4      .62658445      -.20302039
364 O      5      .63179681      -.19842257
365 O      6      .63636621      -.19629289
366 O      7      .63935609      -.19425719
367 O      8      .6399643      -.19384425
368 O      9      .63761242      -.19544323
369 O     10      .63199811      -.19928422
370 O     11      .62315132      -.20543437
371 O     12      .61121913      -.21380306
372 O     13      .59682442      -.22415342
373 O     14      .58066078      -.23612238
374 O     15      .56330426      -.24925696
375 O     16      .5456468      -.26307247
376 O     17      .52828222      -.2771336
377 O     18      .51150752      -.29114798
378 O     19      .49539099      -.3050519
379 O     20      .47964477      -.31906218
380 O     21      .46379155      -.33367714
381 O     22      .44704911      -.34962533
382 O     23      .4267478      -.36727274
383 O     24      .40827225      -.38905014
384 O     25      .38519486      -.41431952
385 O     26      .35944271      -.44437031
386 O     27      .3312262      -.47987532
387 O     28      .30101766      -.52140801
388 O     29      .26947627      -.56947866
389 O     30      .23736425      -.62456468
390 O     31      .20546349      -.68726534
391 O     32      .17452191      -.75815004
392 O     33      .1452141      -.83799122
393 O     34      .11812018      -.92767591
394 O     35      .09371      -1.0282141
395 O     36      .07232567      -1.1407075
396 O     37      .05416176      -1.2663072
397 O     38      .03924964      -1.4061665

```


2-8

```

398 0      39      .02745365      -1.5613998
399 0      40      .01849053      -1.7330506
400 0      41      .01196547      -1.9220701
401 0      42      .00742493      -2.1293077
402 0      43      .00441054      -2.3555086
403 0      44      .00250427      -2.6013169
404 0      45      .00135739      -2.8672939
405 0      46      .0007016      -3.1539078
406 0      47      .00034549      -3.4615645
407 0      48      .00016195      -3.790608
408 0      49      7.2221862E-05      -4.1413313
409 0      50      7.0420704E-05      -4.5139847
410 0
411 0
412 0 01- PLOT STATUS?
413 1 NEW
414 0
415 0 MORE?
416 1 1
417 0
418 0
419 0 6.4E-01+
420 0
421 0
422 0
423 0
424 0 5.3E-01+
425 0 0
426 0 0
427 0
428 0 E
429 0 R 4.2E-01+
430 0 V
431 0 E
432 0 B
433 0
434 0 I 3.1E-01+
435 0 N
436 0 T
437 0 E
438 0 N
439 0 2.0E-01+
440 0 I
441 0 T
442 0 V
443 0
444 0 8.8E-02+
445 0
446 0
447 0
448 0 0.0E+00+
449 0
450 0
451 0 1.0E+00 1.1E+01 2.1E+01 3.1E+01 4.1E+01 5.0E+01
452 0
453 0
454 0 NORMAL RETURN

```

LATERAL INTENSITY PROFILE

ZONE NUMBER

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```

455 0
456 0 03 PLOT STATUS?
457 I NEW
458 0
459 0 NORMAL RETURN
460 0
461 0
462 0 SUBROUTINE NUMBER=?
463 I 5
464 0 WHICH OPTION?
465 I 1
466 0 MAJOR PROFILE INVOLVED=?
467 I 30
468 0
469 0 IN SUBROUTINE ABEL OPTION 1 WILL BE
470 0 PERFORMED ON RINGS OR ZONES 1 TO 50
471 0 PROFILE NUMBERS= 3 4
472 0 IN ABEL, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
473 0 THE LATERAL TO RADIAL INVERSION WILL BE PERFORMED.
474 0 PROFILE 3, THE LATERAL INTENSITY PROFILE
475 0 WILL BE USED AS AN INPUT LATERAL INTENSITY PROFILE.
476 0 PROFILE 4 IS THE BACKLIGHT INTENSITY PROFILE.
477 0 A FULL DREAMS INVERSION WILL BE PERFORMED.
478 0 OUTPUT IS TO PROFILE NUMBER 6
479 0
480 0 SUBROUTINE NUMBER=?
481 I 6
482 0 WHICH OPTION?
483 I 13
484 0 MAJOR PROFILE INVOLVED=?
485 I 6
486 0 SECONDARY PROFILE INVOLVED=?
487 I 0
488 0
489 0 IN SUBROUTINE PRINT-PLOT OPTION 13 WILL BE
490 0 PERFORMED ON RINGS OR ZONES 1 TO 50
491 0 PROFILE NUMBERS= 6 1
492 0 NONE?
493 I 1
494 0
495 0 PROFILE 6, THE COMPUTED EMISSION/ABSORPTION PROFILE IS PRINTED BELOW.
496 0
497 0 INDEX EMISSION/EPSILON.CONC. LOG V(1,J)
498 0 1 241.13091 2.3822529
499 0 2 249.49363 2.3970594
500 0 3 267.14935 2.4267541
501 0 4 292.16181 2.4656234
502 0 5 322.08213 2.5079666
503 0 6 354.09225 2.5491164
504 0 7 385.3402 2.5858443
505 0 8 413.2611 2.6162245
506 0 9 435.82302 2.6393102
507 0 10 451.66422 2.6548156
508 0 11 460.14272 2.6628924
509 0 12 461.32128 2.6640035
510 0 13 455.91109 2.6584801
511 0 14 445.19285 2.6485482

```

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512 0	15	430.88771	2.6343647
513 0	16	414.97118	2.6180179
514 0	17	399.42225	2.6014322
515 0	18	385.94053	2.5865204
516 0	19	375.67574	2.5748131
517 0	20	369.04025	2.5670252
518 0	21	365.65363	2.5630699
519 0	22	364.43585	2.5616211
520 0	23	363.83648	2.5609062
521 0	24	362.13826	2.5588744
522 0	25	357.76906	2.5536028
523 0	26	349.55221	2.543512
524 0	27	336.84723	2.527433
525 0	28	319.57199	2.5045687
526 0	29	298.12275	2.4763951
527 0	30	273.23575	2.4365375
528 0	31	245.83378	2.3906415
529 0	32	216.80107	2.3342612
530 0	33	187.40487	2.2727808
531 0	34	158.25994	2.199371
532 0	35	130.31654	2.1149995
533 0	36	104.3459	2.0184754
534 0	37	81.005746	1.9085158
535 0	38	60.78862	1.7838223
536 0	39	43.968811	1.6431447
537 0	40	30.572385	1.4853293
538 0	41	20.386679	1.3093465
539 0	42	13.010745	1.1143021
540 0	43	7.9329768	.89943618
541 0	44	4.8116754	.66412234
542 0	45	2.557579	.40782905
543 0	46	1.3499929	.13033148
544 0	47	.67717252	-.16930003
545 0	48	.32699374	-.48546056
546 0	49	-.14228371	-.8468448
547 0	50	-.09213902	-1.0355564
548 0			
549 0			
550 0	01. PLOT. STATUS		
551 0	NEW		
552 0			
553 0	NAME?		
554 0	1		
555 0			
556 0		COMPUTED EMISSION/ABSORPTION PROFILE	
557 0	4.6E+02		
558 0	:		
559 0	:		
560 0	:		
561 0	E		
562 0	M 3.8E+02		
563 0	I		
564 0	S		
565 0	:		
566 0	I		
567 0	3.0E+02		
568 0	M		

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```

569 O / : *
570 O E : *
571 O P : *
572 O S 2.2E+02+
573 O I :
574 O L :
575 O O :
576 O M :
577 O . 1.4E+02+
578 O C :
579 O O :
580 O M :
581 O C :
582 O . 6.4E+01+
583 O :
584 O :
585 O :
586 O . 1.2E-02+
587 O X+-----
588 O :
589 O 1.0E+00 1.1E+01 2.1E+01 3.1E+01 4.1E+01 5.0E+01
590 O RING NUMBER
591 O
592 O NORMAL RETURN
593 O
594 O D) PLOT STATUS?
595 I NEW
596 O
597 O NORMAL RETURN
598 O
599 O
600 O SUBROUTINE NUMBER=?
601 I 6
602 O WHICH OPTION?
603 I 3
604 O MAJOR PROFILE INVOLVED=?
605 I 10
606 O
607 O IN-SUBROUTINE PRINT-PLOT-OPTION-3- WILL BE
608 O PERFORMED ON RINGS OR ZONES 1 TO 50
609 O PROFILE NUMBERS= 1 1
610 O
611 O D) PLOT STATUS?
612 I NEW
613 O
614 O HOME?
615 I 1
616 O U.C. RADIAL EMISSION PROFILE
617 O X+-----
618 O 1.0E+03+
619 O :
620 O :
621 O :
622 O :
623 O E 8.3E+02+
624 O L :
625 O A :

```

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```

626 0 T      1
627 0 I      1
628 0 V 4.6E+02+
629 0 E      1
630 0      1
631 0      1
632 0 H      1
633 0 I 4.8E+02+
634 0 S      1
635 0 S      1
636 0 I      1
637 0 0      1
638 0 N 3.1E+02+
639 0      1
640 0 V      1
641 0 A      1
642 0 L      1
643 0 0.1E+02+
644 0 E      1
645 0      1
646 0      1
647 0 0.0E+00+****
648 0 X+-----
649 0      1.1E+01 2.1E+01 3.1E+01 4.1E+01
650 0      1.0E+00
651 0
652 0 RING NUMBER
653 0 NORMAL RETURN
654 0
655 0 0) PLOT STATUS?
656 1 NEW
657 0
658 0 NORMAL RETURN
659 0
660 0
661 0 SUBROUTINE NUMBER=?
662 1 4
663 0 WHICH OPTION?
664 1 3
665 0 MAJOR PROFILE INVOLVED=?
666 1 60
667 0
668 0 IN SUBROUTINE PRINT-PLOT OPTION 3 WILL BE
669 0 PERFORMED ON RINGS OR ZONES 1 TO 50
670 0 PROFILE NUMBERS= 6
671 0
672 0 0) PLOT STATUS?
673 1 OVERLAY
674 0
675 0 HOME?
676 1 1
677 0
678 0 U.C. RADIAL EMISSION PROFILE
679 0 X+-----
680 0 1.0E+01+
681 0      1
682 0      1

```

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```

683 0 R :
684 0 E 8.3E+02+
685 0 L :
686 0 A :
687 0 T :
688 0 T :
689 0 V 6.6E+02+
690 0 E :
691 0 :
692 0 E :
693 0 H :
694 0 T 4.8E+02+
695 0 S :
696 0 S :
697 0 T :
698 0 0 :
699 0 H 3.1E+02+
700 0 :
701 0 V :
702 0 A :
703 0 L :
704 0 H 1.4E+02+
705 0 E :
706 0 :
707 0 :
708 0 0.0E+00+
709 0 :
710 0 :
711 0 1.0E+00 1.1E+01 2.1E+01 3.1E+01 4.1E+01 5.0E+01
712 0 RTIME NUMBER
713 0 :
714 0 NORMAL RETURN
715 0 :
716 0 D) PLOT STATUS?
717 0 I OVERLAY
718 0 :
719 0 NORMAL RETURN
720 0 :
721 0 :
722 0 SUBROUTINE NUMBER=?
723 0 4
724 0 WHICH OPTION?
725 0 50
726 0 :
727 0 IN SUBROUTINE SHIFT OPTION 5. WILL BE
728 0 PERFORMED ON RINGS OR ZONES 1 TO 50
729 0 PROFILE NUMBERS= 3 10
730 0 IN SHIFT, RINGS OR ZONES 1 TO 50 ARE AFFECTED.
731 0 REINITIALIZING SYSTEM
732 0 WHAT IS SPATIAL ZONE SIZE IN MICRONS?
733 0 50
734 0 WHAT IS LAST EMISSION RING?
735 0 25
736 0 SHOULD THE TRANSMITTANCE PROFILE PROTECTION FLAG BE ON?
737 0 RECOMMENDED THAT IT BE ON.
738 0 ENTER "ON" OR "OFF" YOUR CHOICE?
739 0 ON

```

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```

740 0 SHOULD PROFILE 8 BE AUTOMATICALLY CONSTRUCTED?
741 1 YES
742 0
743 0 SUBROUTINE NUMBER=?
744 1 1
745 0 WHICH OPTION?
746 1 2
747 0 MAJOR PROFILE INVOLVED=?
748 1 1
749 0 SECONDARY PROFILE INVOLVED=?
750 1 -2
751 0 NEW DEFAULT SECONDARY PROFILE NUMBER FOR SUBROUTINE CONSTRUC
752 0 ?
753 1 11
754 0 FIRST ZONE OR RING NUMBER=?
755 1 -1
756 0
757 0 IN SUBROUTINE CONSTRUC OPTION 2 WILL BE
758 0 PERFORMED ON RINGS OR ZONES 1 TO 25
759 0 PROFILE NUMBERS= 1 11
760 0 YOU ARE CONSTRUCTING AN OFF-AXIS GAUSSIAN U.C. RADIAL EMISSION
761 0 PROFILE
762 0 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
763 0 MAXIMUM RELATIVE EMISSION VALUE IS=?
764 1 1000
765 0 GAUSSIAN CENTERED IN ZONE OR RING?
766 1 10
767 0 GAUSSIAN HALF WIDTH AT HALF HEIGHT?
768 1 5
769 0
770 0 SUBROUTINE NUMBER=?
771 1 1
772 0 WHICH OPTION?
773 1 2
774 0 MAJOR PROFILE INVOLVED=?
775 1 2
776 0 SECONDARY PROFILE INVOLVED=?
777 1 0
778 0 FIRST ZONE OR RING NUMBER=?
779 1 -2
780 0
781 0 IN SUBROUTINE CONSTRUC OPTION 2 WILL BE
782 0 PERFORMED ON RINGS OR ZONES 26 TO 50
783 0 PROFILE NUMBERS= 2 11
784 0 YOU ARE CONSTRUCTING AN OFF-AXIS GAUSSIAN U.C. RADIAL ABSORPTION
785 0 PROFILE
786 0 WHICH WILL BE ADDED TO THE CURRENT CONTENTS OF THAT PROFILE.
787 0 MAXIMUM EPSILON CONCENTRATION IS=?
788 1 5.0
789 0 GAUSSIAN CENTERED IN ZONE OR RING?
790 1 35
791 0 GAUSSIAN HALF WIDTH AT HALF HEIGHT?
792 1 5
793 0
794 0 SUBROUTINE NUMBER=?
795 1 6
796 0 WHICH OPTION?

```

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```

797 I 13
798 O MAJOR PROFILE INVOLVED=?
799 I 8
800 O SECONDARY PROFILE INVOLVED=?
801 I 00
802 O
803 O IN SUBROUTINE PRINT-PLOT OPTION 13 WILL BE
804 O PERFORMED ON RINGS OR ZONES 1 TO 50
805 O PROFILE NUMBERS= 1 1
806 O NOPE?
807 I 1
808 O
809 O PROFILE 8, THE U.C. EMISSION/ABSORPTION PROFILE IS PRINTED BELOW.
810 O
811 O INDEX EMISSION/EPSILON.CONC LOG.V(I,J)
812 O 1 105.84316 2.0246628
813 O 2 169.57553 2.2293632
814 O 3 257.02845 2.4099812
815 O 4 368.5673 2.5665168
816 O 5 499.99998 2.69897
817 O 6 641.71294 2.8073408
818 O 7 779.16457 2.8916292
819 O 8 895.02506 2.9518352
820 O 9 872.45494 2.9179588
821 O 10 1000 3.
822 O 11 972.65494 2.9879588
823 O 12 195.02506 2.9518352
824 O 13 779.16457 2.8916292
825 O 14 641.71294 2.8073408
826 O 15 499.99998 2.69897
827 O 16 368.5673 2.5665168
828 O 17 257.02845 2.4099812
829 O 18 169.57553 2.2293632
830 O 19 105.84316 2.0246628
831 O 20 62.499993 1.79588
832 O 21 31.91522 1.5430748
833 O 22 18.45301 1.2666672
834 O 23 9.2265042 .96503717
835 O 24 4.3644025 .63992479
836 O 25 1.9531266 .29072995
837 O 26 .52921579 -.2763721
838 O 27 .84787767 -.0716668
839 O 28 1.2851423 .1089512
840 O 29 1.8428365 .2654668
841 O 30 2.4999999 .39793999
842 O 31 3.2085647 .50631079
843 O 32 3.8958229 .59059919
844 O 33 4.4751253 .6508052
845 O 34 4.8632747 .68692879
846 O 35 5 .69897
847 O 36 4.8632747 .68692879
848 O 37 4.4751253 .6508052
849 O 38 3.8958229 .59059919
850 O 39 3.2085647 .50631079
851 O 40 2.4999999 .39793999
852 O 41 1.8428365 .2654668
853 O 42 1.2851423 .1089512

```


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854 0	43	.84787767	-.0716668
855 0	44	.52921579	-.27636721
856 0	45	.31249997	-.50515002
857 0	46	.1745761	-.7580132
858 0	47	.09226505	-1.0349628
859 0	48	.04413252	-1.3359028
860 0	49	.02182201	-1.6411052
861 0	50	.00976562	-2.0103
862 0			
863 0	PLOT OPTIONS. SHOULD ABSORPTION REGION'S PLOT SYMBOL BE DISTINCT		
864 0	?		
865 1	YES		
866 0	PLOT HAS 2 DIFFERENT SYMBOLS.		
867 0	SHOULD ABSORPTION REGION BE SCALED THE SAME AS THE EMISSION REGION		
868 0	?		
869 1	NO		
870 0			
871 0	BY PLOT STATUS?		
872 1	NEW		
873 0			
874 0	NONE?		
875 1	1		
876 0			
877 0	U.C. EMISSION/ABSORPTION PROFILE		
878 0	1.0E+03+	*	A
879 0	:	**	AA
880 0	:		
881 0	:	*	A
882 0	E	:	
883 0	M 8.3E+02+		
884 0	I	:	A
885 0	S	:	
886 0	T	:	
887 0	I	:	
888 0	6.6E+02+	*	A
889 0	M	:	
890 0	/	:	
891 0	E	:	
892 0	P	:	
893 0	4.8E+02+	*	A
894 0	I	:	
895 0	T	:	
896 0	O	:	A
897 0	M	:	
898 0	3.1E+02+		
899 0	C	:	
900 0	O	:	A
901 0	R	:	
902 0	C	:	A
903 0	1.4E+02+	*	A
904 0	:	:	
905 0	:	:	
906 0	:	:	AA
907 0	0.0E+00+	*	AAA
908 0	X+		
909 0	1.0E+00	1.1E+01	2.1E+01
910 0	3	3.1E+01	4.1E+01
			5.0E+01

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```

911 0
912 0
913 0 NORMAL RETURN
914 0
915 0
916 0
917 0
918 0
919 0
920 0 NORMAL RETURN
921 0
922 0
923 0 SUBROUTINE NUMBER=?
924 I 2
925 0 WHICH OPTION?
926 I 1
927 0 MAJOR PROFILE INVOLVED=?
928 I 80
929 0
930 0 IN SUBROUTINE FORWARD OPTION 1 WILL BE
931 0 PERFORMED ON RINGS OR ZONES 1 TO 50
932 0 PROFILE NUMBERS= 8 2
933 0 CONSTRUCTING DEFAULT BACKLIGHT PROFILE.
934 0 V(L) IS 100 IN ALL ZONES 1 TO 50
935 0 IN FORWARD, PROFILE 0, THE U.C. EMISSION/ABSORPTION PROFILE
936 0 WAS USED AS AN INPUT RADIAL EMISSION PROFILE.
937 0 IN FORWARD, PROFILE 0, THE U.C. EMISSION/ABSORPTION PROFILE
938 0 WAS USED AS AN INPUT RADIAL ABSORPTION PROFILE.
939 0 OPERATING LIMITS WERE ZONES AND RINGS 1 TO 50
940 0 OPTION 1 WAS EXECUTED IN FORWARD.
941 0 OPERATION DESCRIPTION:
942 0 COMPLETE RADIAL TO LATERAL EMISSION/ABSORPTION CALCULATION PERFORMED.
943 0
944 0 SUBROUTINE NUMBER=?
945 I 6
946 0 WHICH OPTION?
947 I 13
948 0 MAJOR PROFILE INVOLVED=?
949 I 30
950 0
951 0 IN SUBROUTINE PRINT-PLOT OPTION 13 WILL BE
952 0 PERFORMED ON RINGS OR ZONES 1 TO 50
953 0 PROFILE NUMBERS= 3 1
954 0 HOWE?
955 I 1
956 0
957 0 PROFILE 3, THE LATERAL INTENSITY PROFILE IS PRINTED BELOW.
958 0
959 0 INDEX OBSERVED INTENSITY LOG V(I,J)
960 0 1 .28789546 -.54076518
961 0 2 .29313855 -.53292706
962 0 3 .30187176 -.52017751
963 0 4 .3126277 -.50497253
964 0 5 .32349662 -.49013053
965 0 6 .33204661 -.47880094
966 0 7 .33554683 -.47422097
967 0 8 .33153908 -.47946527

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968 0	9	.31821864	-.49727438
969 0	10	.29513543	-.52997866
970 0	11	.26333218	-.57949606
971 0	12	.22322966	-.64737402
972 0	13	.18414113	-.73484918
973 0	14	.14357874	-.84290986
974 0	15	.10657284	-.97235346
975 0	16	.07519044	-1.1236374
976 0	17	.05035879	-1.2979247
977 0	18	.03197928	-1.4951313
978 0	19	.01923157	-1.7159853
979 0	20	.0109363	-1.9611296
980 0	21	.00586755	-2.2315433
981 0	22	.00295721	-2.529118
982 0	23	.00138534	-2.858444
983 0	24	.00058352	-3.2339431
984 0	25	.00018298	-3.7375887
985 0	26	.13.836976	1.1410412
986 0	27	12.220963	1.0871054
987 0	28	10.712234	1.02988
988 0	29	9.41397	.97377279
989 0	30	8.4169855	.92515657
990 0	31	7.7947985	.89180488
991 0	32	7.4155415	.82120192
992 0	33	7.9689386	.90140047
993 0	34	9.0019219	.95433523
994 0	35	10.953196	1.0396201
995 0	36	14.183426	1.1517811
996 0	37	19.124908	1.2815993
997 0	38	24.173632	1.417864
998 0	39	35.442374	1.5495228
999 0	40	46.516342	1.6676056
1000 0	41	58.401589	1.7664246
1001 0	42	69.799273	1.8438509
1002 0	43	79.575856	1.9007813
1003 0	44	87.122631	1.940131
1004 0	45	92.412442	1.9657304
1005 0	46	95.812501	1.9814221
1006 0	47	92.83512	1.9904945
1007 0	48	98.958155	1.9954516
1008 0	49	99.546388	1.9980255
1009 0	50	99.850454	1.9993509
1010 0			
1011 0	PLOT OPTIONS. SHOULD ABSORPTION REGION'S PLOT SYMBOL BE DISTINCT		
1012 0	1		
1013 0	1 YES		
1014 0	PLOT HAS 2 DIFFERENT SYMBOLS.		
1015 0	SHOULD ABSORPTION REGION BE SCALED THE SAME AS THE EMISSION REGION		
1016 0	1		
1017 0	1 YES		
1018 0			
1019 0	PLOT STATUS?		
1020 0	NEW		
1021 0			
1022 0	NONE?		
1023 0	1		
1024 0	LATERAL INTENSITY PROFILE		

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```

1025 0 1.0E+02+
1026 0 1.0E+02+
1027 0 1.0E+02+
1028 0 1.0E+02+
1029 0 1.0E+02+
1030 0 1.0E+02+
1031 0 8.3E+01+
1032 0 0
1033 0 0
1034 0 0
1035 0 0
1036 0 4.5E+01+
1037 0 0
1038 0 0
1039 0 0
1040 0 0
1041 0 4.8E+01+
1042 0 0
1043 0 0
1044 0 0
1045 0 0
1046 0 3.1E+01+
1047 0 0
1048 0 0
1049 0 0
1050 0 0
1051 0 1.4E+01+
1052 0 0
1053 0 0
1054 0 0
1055 0 0.0E+00+
1056 0 0
1057 0 0
1058 0 1.0E+00
1059 0 1.0E+00
1060 0 1.0E+00
1061 0 NORMAL RETURN
1062 0
1063 0
1064 0 03 PLOT STATUS?
1065 0 03 PLOT STATUS?
1066 0 03 PLOT STATUS?
1067 0 03 PLOT STATUS?
1068 0 03 PLOT STATUS?
1069 0 03 PLOT STATUS?
1070 0 SUBROUTINE NUMBER=?
1071 0 4
1072 0 WHICH OPTION?
1073 0 3
1074 0 MAJOR PROFILE INVOLVED=?
1075 0 30
1076 0
1077 0 IN SUBROUTINE PRINT-PLOT OPTION 3 WILL BE
1078 0 PERFORMED ON RINGS OR ZONES 1 TO 50
1079 0 PROFILE NUMBERS= 3 1
1080 0 PLOT OPTIONS. SHOULD ABSORPTION REGION'S PLOT SYMBOL BE DISTINCT
1081 0 ?

```

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```

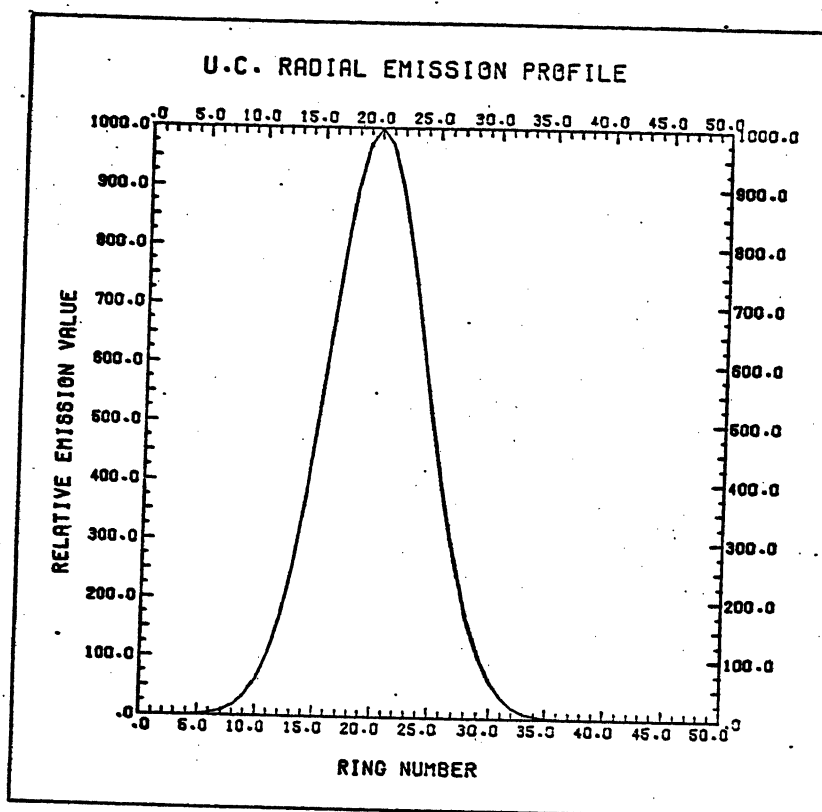
1082 I YES
1083 0 PLOT HAS 2 DIFFERENT SYMBOLS.
1084 0 SHOULD ABSORPTION REGION BE SCALED THE SAME AS THE EMISSION REGION
1085 0 ?
1086 I NO
1087 0
1088 0 D) PLOT STATUS?
1089 I NEW
1090 0
1091 0 NONE?
1092 I 1
1093 0
1094 0
1095 0 3.4E-01+
1096 0
1097 0
1098 0
1099 0
1100 0 2.8E-01+
1101 0 0
1102 0 0
1103 0 0
1104 0 0
1105 0 2.2E-01+
1106 0 V
1107 0 0
1108 0 0
1109 0
1110 0 I 1.6E-01+
1111 0 0
1112 0 T
1113 0 E
1114 0 W
1115 0 S 1.0E-01+
1116 0 I
1117 0 T
1118 0 V
1119 0
1120 0 4.4E-02+
1121 0
1122 0
1123 0
1124 0 0.0E+00+
1125 0
1126 0
1127 0 1.0E+00
1128 0
1129 0
1130 0 NORMAL RETURN
1131 0
1132 0
1133 0 D) PLOT STATUS?
1134 I NEW
1135 0
1136 0
1137 0 NORMAL RETURN
1138 0

```

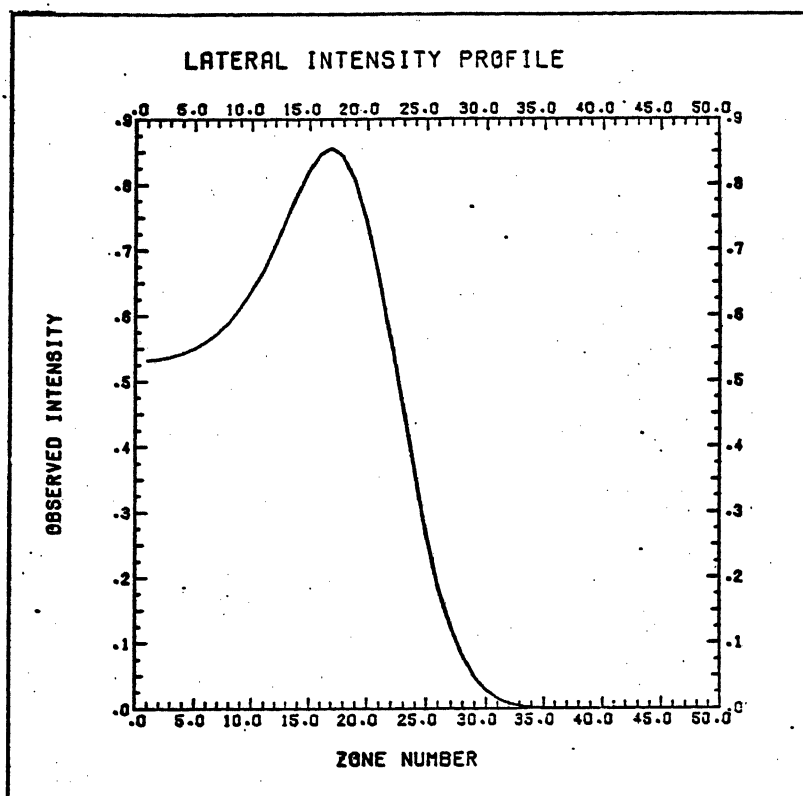
LATERAL INTENSITY PROFILE

ZONE NUMBER

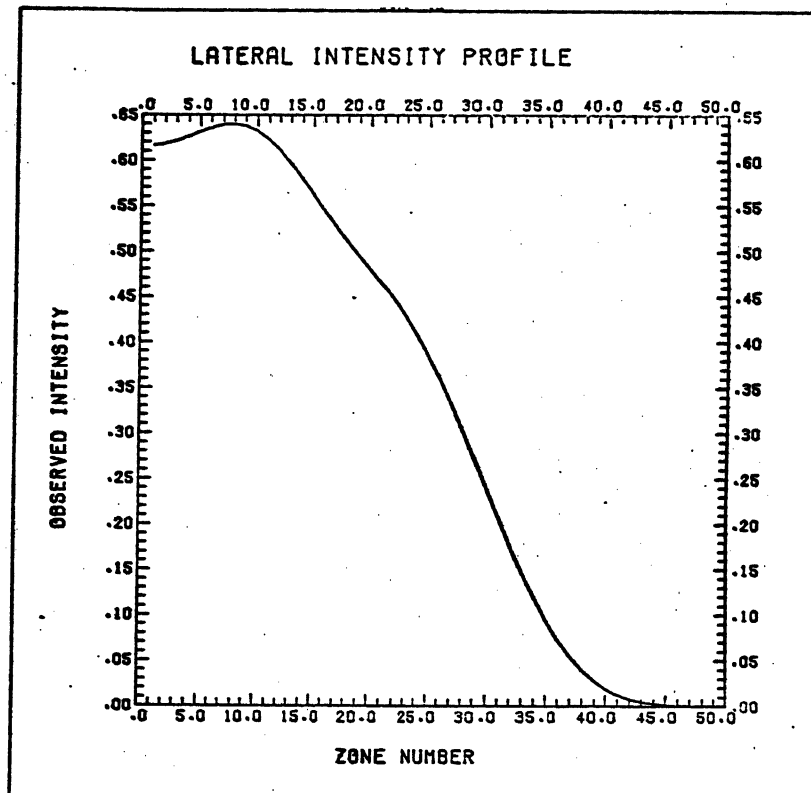
E-22



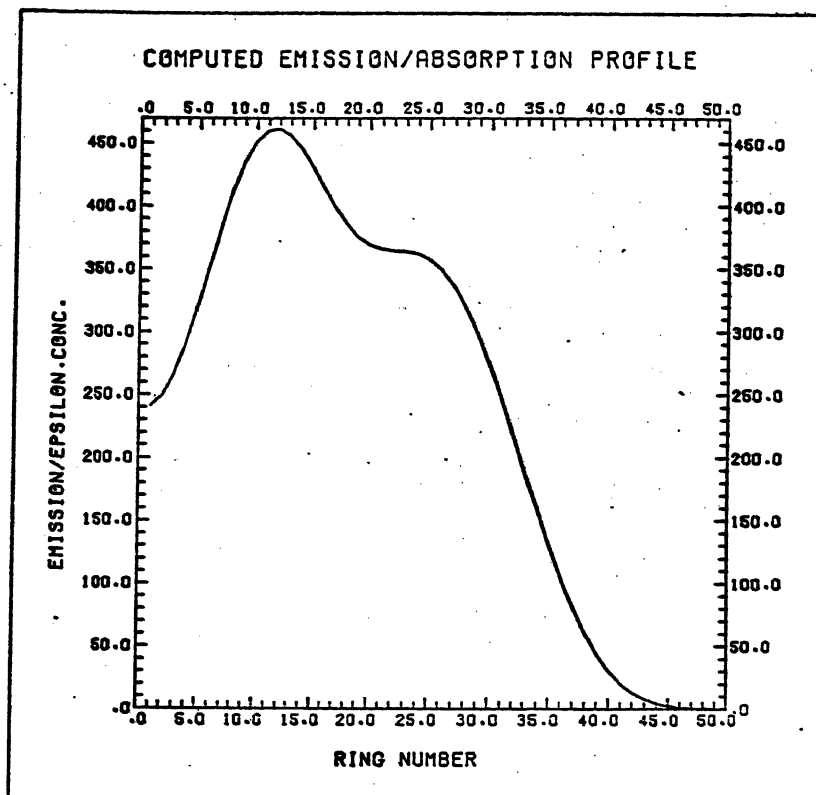
E-23



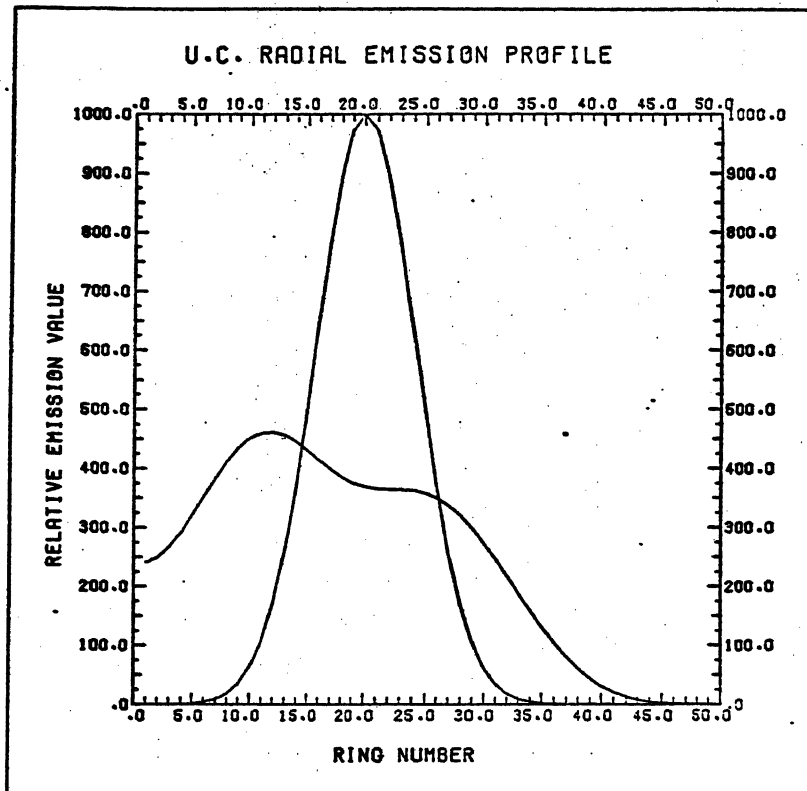
B-24



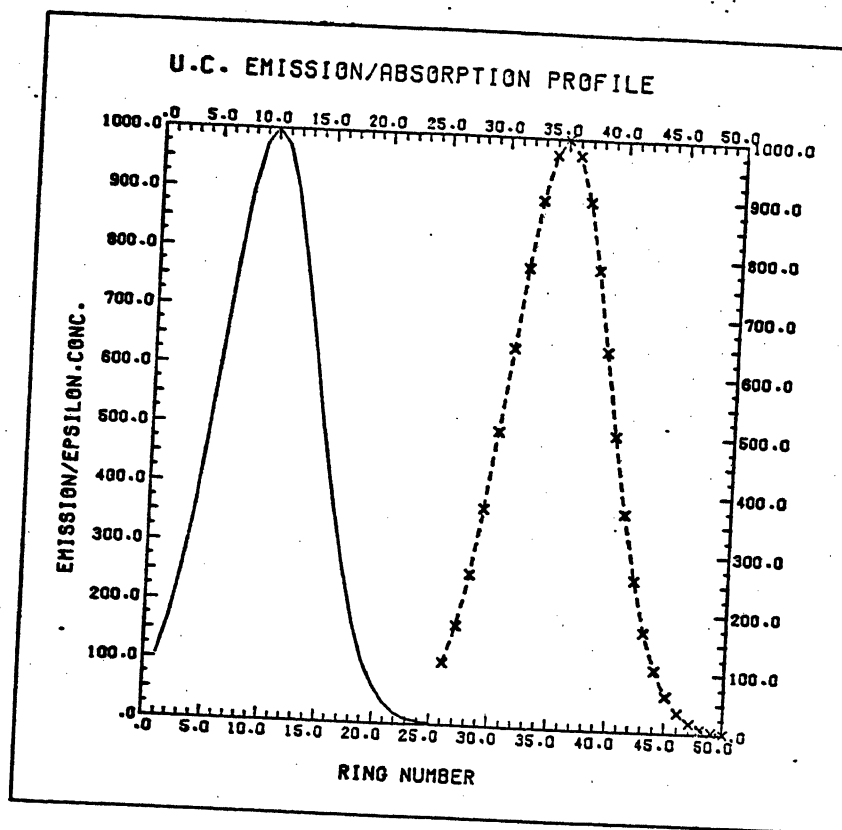
E-25



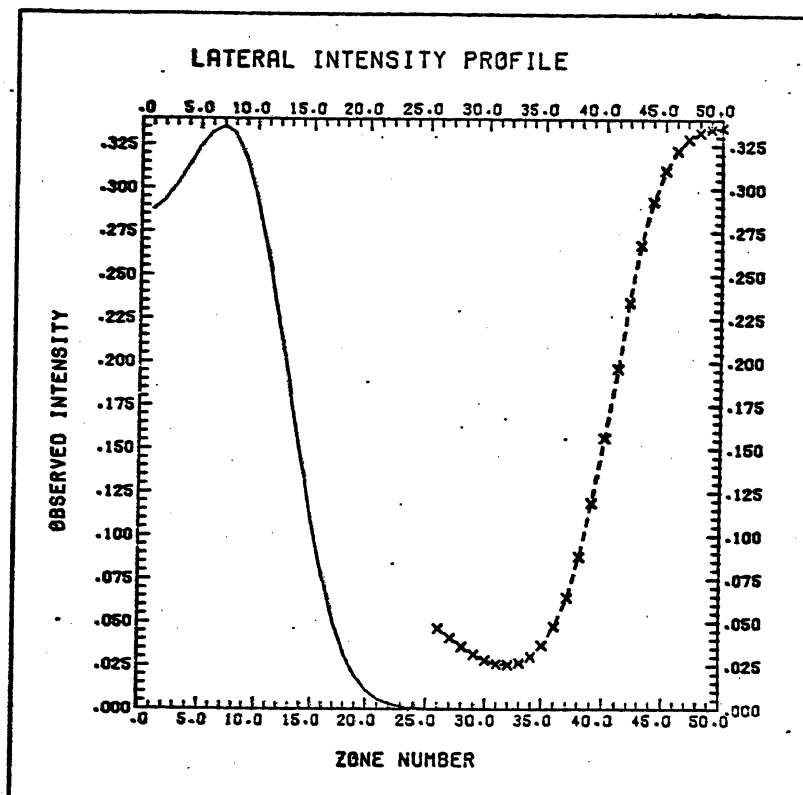
E-26



E-27



2-28



Appendix B

PEPSUB

The software documented in this appendix was originally written by Dean T. Stueland. The present author has made some revisions in both the software and documentation.

I. Introduction

PEPSUB is a subroutine, written in BASIC, used to accept data from a PEP terminal and, by linking to a FORTRAN program, display it again at the same terminal. The heart of the system are FORTRAN subroutines available at MACC for plotting on the CalComp plotter or at a PEP terminal. However, it is not possible to call FORTRAN subroutines from BASIC so PEPSUB writes a file, named PLOT, which contains instructions and data. This file is then read by a FORTRAN program, called BASIC-PEP, which calls the appropriate routines.

There are several options available to a user of MACC's graphing subroutines. It could be difficult specifying all of these options at one time. So, to make the use of PEPSUB easier, certain options, which are not likely to be changed, are kept

constant and the user need not worry about them. The other options are handled by one of two methods:

- (1) The user specifies each option one at a time and PEPSUB only advances to the next option when an acceptable response has been given to the present one.
- (2) The user may elect not to use the options. In this case, PEPSUB supplies a default value for each of the options. It is also possible to get the default value for a given option when using the first method of specifying options.

If the user selects the first method, he can switch to the second method partway through the sequence. However, once he has selected the second method, it is not possible to switch to the first since there is no opportunity for user input until after the options have been supplied by PEPSUB.

The data to be graphed can be entered into PEPSUB in one of two ways. It is possible to fill arrays with data in the calling program which are then passed to PEPSUB. Also, it is possible to enter the data into the computer in pairs, where the first number is the abscissa and the second is the ordinate. A special pair signals PEPSUB that all the data has been entered and control is returned to the calling program.

If at any time, one discovers that he has made a mistake or has some other reason for wanting to get out of PEPSUB, there is

a special command which immediately allows one to exit from PEPSUB. Although this immediate return can be used anywhere within the subroutine, PEPSUB insures that the file is kept in order by writing out default values for each of the options and by placing an appropriate flag after the options which indicate that they are not to be used. This method of return is called an "escape return".

Besides receiving the plot on the PEP screen, it is possible to request the data to also be plotted on the CalComp plotter. PEPSUB accepts the options while BASIC-PEP (see below) displays the data at the PEP screen and allows the user to decide if the data should be plotted on the CalComp.

The FORTRAN program, BASIC-PEP, works in a two step process. First, it assigns a temporary drum file and loads all the instructions and data onto it. It reads the data from the file prepared by PEPSUB and checks if an "escape return" has been used. The instructions which are flagged as belonging to an "escape return" are not saved in the drum file. The first pass through the data gives BASIC-PEP two features:

- (1) BASIC-PEP can interact with the user through the standard input file. It can respond immediately to the user's input without interfering with the reading of the data.

- (2) As part of its control, BASIC-PEP needs to only read the next line in the drum file to know what sort of function is next. Otherwise, it would be necessary for BASIC-PEP to process a whole block of data before it would find out if an "escape return" had been used.

It closes this phase of the run by giving the number of successful calls to PEPSUB (called "normal returns") and the number of "escape returns".

In the second phase, BASIC-PEP reads through the drum file written in the first phase and displays each block of data. Then if the user wishes, it also commands the data to be plotted on the CalComp plotter.

A description of the routines used by BASIC-PEP is found in three different MACC manuals:

- (1) Graphics Handbook
- (2) Graph: Complete Graph Plotting Routine
- (3) The GSP Primer.

A listing of BASIC-PEP appears in Appendix B-3.

II. Instructions for Programming

Since PEPSUB is meant to be used as a subroutine, it is necessary for the user to provide a calling program. BASIC will then replace the call to PEPSUB by GOSUB 9000, but only if the user's program file contains PEPSUB. It can be put into a file in one of three ways:

- (1) If PEPSUB is in a file, such as CHEMISTRY*WALTERS, it can be copied into the user's file by a statement of the form

```
@COPY,SC CHEMISTRY*WALTERS.PEPSUB,NEW*FILE.
```

where NEW*FILE. could be replaced by the name of any user file.

- (2) If PEPSUB is not in a file, it can be loaded from cards, using BASIC. An example is:

```
@BASIC NEW*FILE.
```

```
NEW:PEPSUB
```

```
PEPSUB program cards
```

```
SAVE
```

```
BYE
```

where NEW*FILE. could again be any user file.

- (3) Another way to load PEPSUB from cards is to use the ELT processor, which reads directly from cards to memory. This method will not produce a deck listing.

@ELT,SI NEW*FILE.PEPSUB

PEPSUB program cards

If the user file needs a write key, then the file should be assigned, before either the COPY, ELT, or BASIC statement with the write key.

When BASIC incorporates PEPSUB into another program, each line from PEPSUB is written into the new program. Therefore after PEPSUB has been incorporated into the new program, there is no reason to save it unless usage in other programs is envisaged. It can be deleted and the file packed if appropriate by statements of the following type:

@DELETE,SC NEW*FILE.PEPSUB

@PACK NEW*FILE.

or, using BASIC

@BASIC NEW*FILE.

OLD:PEPSUB

UNSAVE

BYE

@PACK NEW*FILE.

where NEW*FILE could be any user file and should be assigned with a write key if one is needed. It must be remembered that PEPSUB must be in the user file when the calling program is written.

There are six points to remember in writing a program to use PEPSUB:

- (1) There must be at least one statement of the form:

```
m CALL PEPSUB
```

When BASIC encounters this statement, it will incorporate PEPSUB into the program and change the above statement to

```
m GOSUB 9000
```

- (2) The statements number 9000 through 10000 cannot be used by the calling program since there are reserved for PEPSUB.
- (3) Certain variables must be included and others may not be used. Since PEPSUB is prepared to accept data from arrays named X and Y, they must be provided in the calling program using the DIM statement, which must be numbered less than 9000 since arrays must be dimensioned before they are used. If the X and Y arrays will not be used, a statement of the form

```
m DIM X(1),Y(1)
```

is adequate. If the arrays will be used a statement of the form

```
m DIM X(100),Y(100)
```

is necessary. The X and Y arrays must be dimensioned large enough so that all points for one plot may be loaded simultaneously into the arrays.

No variable name using the letter Z can be used by the calling program. These letters are reserved for use as flags by PEPSUB. The variables which are used and their use is listed in Appendix B-1.

- (4) The calling program needs no END statement since PEPSUB supplies one at statement number 99999.
- (5) The calling program may use files, but it must not use a file numbered 9 because this is the file number on which PEPSUB writes. Likewise, the calling program must not write on a file or read from a file named PLOT because that is the file which PEPSUB uses.
- (6) Once a statement

```
m CALL PEPSUB
```

has appeared in a user's program, further PEPSUB calls can most economically be achieved by saying

```
n GOSUB 9000
```

Saying "Call Pepsub" each time one desires to call the subroutine will result in the subroutine being repeatedly reread from the drum file, which is needlessly consumptive of execution time and money.

A listing of PEPSUB is shown in Appendix B-2 along with a flowchart of the routine.

III. Instructions for Using PEPSUB

When PEPSUB has been correctly included into a program, one can use it simply by instructing BASIC to run the program. When PEPSUB is called the first statement from PEPSUB will be the statement:

ENTER PEP SUBROUTINE

Then it will proceed to ask information from the user. This section goes over each question and the allowable responses.

Before going into each question in detail it is necessary to remember certain responses which have special meaning.

- (1) "-1" is used to get an escape return. When it is used as a response to any question, PEPSUB immediately gives up control of the run and returns to the calling program. It will print out the message

ESCAPE RETURN

- (2) "-2" is used to get the default value when one is available.
- (3) "-3" is used to get out of the options section. It is used when one has asked for options, but then realizes that he does not want options.

The following is a description of each question and its possible answers.

(A) SHOULD CALCOMP PLOTTER CAPABILITY BE TURNED ON?

This question is to find out if any of the plot in the run will be saved on paper by the CalComp. If one answers affirmatively, he is still not forced to save any plot. However, if one answers negatively, he cannot get any hard copy plot. There is an advantage to answering negatively, though, because the program runs a little more cheaply and rapidly if it does not need to worry about hard copy plotting, and there is a small savings in file charges. The possible answers are "YES" and "NO". The default value yields "YES".

(B) PAPER SIZE ("LARGE" OR "SMALL")?

Plotting paper at MACC comes in rolls of two sizes, 30-inch (29.3 inches available for actual plotting) and 11-inch (10.8 inches available). The 30-inch paper is "LARGE" and the 11-inch paper is "SMALL". The available width (29.3 inches or 10.8 inches) must be greater than or equal to the small of the dimensions which can be specified in questions L-2 and L-3 concerning the size of the plot. The default value is "SMALL".

This question is only asked if the answer to question (A) was affirmative, since it has no meaning if no plotter paper is being used.

(C) LIQUID INK ("YES" OR "NO")?

The standard pen used on the plotter is ball-point. This is not adequate for some purposes, such as being able to make xerox copies of the plots. It is possible to instruct that a liquid ink pen be used. This results in a higher quality plot, but is more expensive since the plotter is then run at one-half speed. The default value is "NO".

This question is also not asked unless the answer to question (A) was affirmative.

Question (A), (B), and (C) are only asked once in a run. Once the paper and pen have been chosen, they cannot be changed. However, if the escape return is used from any one of these three questions, they will all be repeated since they are considered together.

(D) TYPE OF PLOT: NEW, OVERLAY, OR NONE?

There are two ways in which one may use data in PEPSUB. The data may be plotted as it stands, in which case one is making a NEW plot, or the data may be superimposed on the last preceding NEW plot, i.e. overlaid on that previous plot. To obtain a new plot with fresh axes,

labels, options, etc., the plot type entered is NEW; similarly to overlay plots a plot type of OVERLAY is entered. The default type is NEW. Each time PEPSUB is called, one NEW or OVERLAY plot may be generated.

If a plot type of NONE is chosen, all plotting functions are skipped and question (N) concerning whether any further plots are to be generated is asked. This allows one to enter PEPSUB inadvertently without affecting the plot file or to enter PEPSUB solely for the purpose of closing the plot file or initiating actual plot generation.

(E) OPTIONS?

As mentioned in the introduction, it is possible to either specify the options or request that the default values be used. This question controls which method will be used. The affirmative answer ("YES") will result in the options being requested from the user so that the next question is (F). The negative answer ("NO") will result in the default values being used for the options so that the next question is (M). The default value is "NO".

(F) TITLE?

The title can be any combination of letters, numbers, and symbols as long as there are no more than 60

characters and the first character is not "@". The default value is "PLOT n" where n refers to the n-th call to PEPSUB.

(G) X AXIS LABEL?

This label has the same restrictions as the title.

The default value is "X AXIS".

(H) Y AXIS LABEL?

This label has the same restrictions as the title and the label for the x axis. The default value is "Y AXIS".

(I) SYMBOL CODE?

It is possible, but not necessary to have a symbol displayed at each data point. The possible codes are zero through fifteen and are shown in Appendix B-4. The default value is not to display any symbol. The only way not to use a symbol is to use the default code.

(J) DASH CODE?

It is possible, but not necessary to have line segments which connect the data points. The possible codes are zero through twenty-three. The codes one through twenty-three are the dashed patterns as shown in Appendix B-4. Zero is a special code which means no line segment between points. The default value is a solid line. To get a solid line, one must use the default code.

- (K-1) MAXIMUM (X AXIS)?
- (K-2) MINIMUM (X AXIS)?
- (K-3) MAXIMUM (Y AXIS)?
- (K-4) MINIMUM (Y AXIS)?

The above four questions are considered together because it is necessary to answer each correctly to make this option work. The default response to any one of the questions causes the default value for the whole option. The default option is for the axis scales to be adjusted to just accommodate the maximum and minimum along each axis. However, by specifying the maximum and minimum values in this option it is possible to make different scales along the axes. Note that maxima may not be equal to minima, otherwise no plot is generated. The program checks for this conflict and reasks the max./min. question until a satisfactory answer is received.

(L) SPECIAL PAGE CODE?

This option specifies the size of the page used for the plot. It only applies to plot coming off the plotter since the size of the screen at the PEP is fixed. If the answer to question (A) was "NO" this question will never appear and the next question after (K-4) would be (M).

There are two ways to specify the size of the page to be used. The first way is to specify the pair of options from Appendix D of the MACC manual, CONTOUR (see Appendix B-4, last two pages). In this case, the response to this question should be the first of the pair. After checking if the response is legitimate, the next question will be (L-1). The second possibility is to specify the length and width (in inches) of the page to be formed. In this case, the response to this question is NUMBER and the next question is (L-2). The default option is for a square page of the maximum possible size (10.8 inches by 10.8 inches if the response to question (B) was SMALL; 29.3 inches by 29.3 inches if the response to questions (B) was LARGE).

(L-1) SECOND OPTION?

If the response to question (L) was the first of a pair for an option from Appendix E of GRAPH, this is asking for the second of the pair. Following this, the next question is question (M).

(L-2) SIZE OF X AXIS?

(L-3) SIZE OF Y AXIS?

If the response to question (L) was NUMBER, this is requesting the size n inches of each of the two axes. The smaller axes must be no more than the paper width (10.8 inches or 29.3 inches) and the larger axes must

be no more than fifty inches. Following the correct answer to these, the next question is (M).

(M) DATA FROM PEP OR X & Y ARRAYS
ANSWER ("PEP" OR "XY")?

As mentioned previously, there are two ways by which PEPSUB can accept data. The first way is to take the data from arrays which were written by the calling program. This is the response XY. The abscissa is taken from the X array and the ordinate from the Y array. In this case, the next question is (M-2).

The second method of accepting data is to take it directly from the PEP. This option works in the following way. First, PEPSUB prints out the following message:

(M-1) INPUT THE COORDINATES BY PAIRS
POINT 1 = ?

To this the user responds with the abscissa and the ordinate in the following manner:

$$X_1, Y_1$$

Both the abscissa and ordinate (separated by a comma) must be included in the response. After accepting the two values PEPSUB goes on to request the second and third pair of values and so on so that the i -th value is requested as:

POINT 1 = ?

and the user responds

X_1, Y_1

To stop inputting values, the user responds with the values

-2,-2

At this time, PEPSUB prints out the following message

NORMAL RETURN

and control is returned to the calling program.

The special response

-1,-1

is recognized as calling for the escape return. To enter data points which are numerically equal to commands, change the data slightly so that no change will be apparent on the plot but the typed in data will no longer be the same as a command. For example, to plot the point (-1,-1), the input response could be

-1.000001,-1.000001

(M-2) HOW MANY POINTS?

PEPSUB branches to this question if the answer to question (M) was XY. It wants to know how many values out of the X and Y arrays should be used. The user responds with some value, N, which is no more than 250 and no less than one. PEPSUB then takes the first N values out of each array as the abscissa and ordinates for the N points.

(N) DONE WITH PLOTTING FOR THIS RUN?

When the user has entered the last of the data to be plotted into PEPSUB, the plot file must be closed so that the FORTRAN program, BASIC-PEP, can actually produce the plots. To inform the program that no more plot data will be entered, question (N) is answered either YES or Y. To be able to generate further plot data, the answers -3, -2, -1, NO or N are acceptable. If any of the latter five answers is given, PEPSUB immediately returns run control to the calling program. If the answer to question (N) is YES or Y, question (O) is then asked.

Once question (N) is answered affirmatively, further calls to PEPSUB will generate a diagnostic, followed by question (O).

- (0) TO PLOT ON THE PEP TERMINAL IMMEDIATELY, TYPE 'PEP' OTHERWISE TYPE 'TTY' OR 'BATCH'?

Only the three words listed in the question are legal responses to question (0); no default exists. To immediately call BASIC-PEP and generate plots, the correct answer is PEP; to return program control to the user's BASIC program, either TTY or BATCH may be entered with equal affect. If either TTY or BATCH is the answer to question (0), a later call to PEPSUB will allow the user once again to choose among the three responses. When control of the program is returned from PEPSUB to the calling program following questions (N) or (0), PEPSUB prints NORMAL RETURN to indicate that all is in order. After such a return, PEPSUB may be called again at any time by the main calling program.

Note that the last input a user can give while still in BASIC is the answer PEP--this response triggers a chain of events which stops the user's program, terminates BASIC, and starts plot generation. If one does not wish to generate plots immediately following the running of his BASIC program, one may preserve the plot file for future use by entering the statement

@SAVE,S PLOT.

after a BYE command in BASIC and before he says @FIN. The plots may then be accessed as described below. If the plot file is not to be used after 4:30 A.M. on the morning following plot file production, the @SAVE command is not needed. If the file was saved, it may be erased by entering the statement

@DELETE PLOT.

The above sequence of questions may be altered by different situations. However, the change is always in the direction of skipping questions, never altering the order. The conditions where the questions can be skipped are as follows:

- (1) After a call to PEPSUB which successfully reaches question (D), there is no longer any need for questions (A) through (C) and they are skipped by any subsequent calls to PEPSUB.
- (2) If the response to question (D) is OVERLAY, then PEPSUB automatically skips to questions (I), (J), and then (M). However since question (I) is in the option section, the special response -3 will cause question (J) to be skipped so that the next questions is (M).
- (3) Whenever the response to question (E) is NO or -2, questions (F) through (L) are given the default values and the next question is (M).

- (4) After question (N) has been answered affirmatively, the only question which will be asked on further calls is question (0).

To produce plots a second time, to produce plots at the PEP terminal after a teletype or batch run, or to obtain plots if one never answered PEP in question (0) even though that was the user's intent, one may enter the following sequence of statements:

@ASG,A PLOT.

@ADD,P PLOT.

This is done automatically for the user if question (0) is answered PEP.

Note that if hard copy is to be obtained, one should not rerun the plotting routine in the same run in which the plots were generated. If such duplication is attempted, all hard copy may be destroyed.

IV. Error Messages

PEPSUB cannot prevent all errors, but it tries to help by only accepting certain responses. If it does not recognize the response to any question, it repeats the question. Note this does not prevent the problem that certain responses, which may be legal are not acceptable in certain cases. For these cases, PEPSUB prints out warning messages. This section goes through the messages printed by PEPSUB and explains what they mean. Note that all of these messages are preceded by two asterisks.

****YOU CANNOT DO AN OVERLAY WITHOUT AT LEAST ONE NEW PLOT**

This message is displayed when one answers OVERLAY to question (D) before there has been a successful plot. Question (D) is repeated until one chooses NEW, NONE, or -2.

****BUT YOU HAVE NO SYMBOL EITHER**

This message occurs when the response to (I) (symbol code) is -2, indicating no symbol and the response to question (J) (line code) is zero, indicating no line. If these responses were accepted, one would get a plot with no data displayed. Question (J) is repeated so that one can choose a different line code.

****THE MAX & MIN CANNOT BE EQUAL**

This is printed during any part of question (K) if the maximum and minimum values for either axes are equal. Just the maximum and minimum values for the axis concerned are requested again.

****THE OPTIONS OPTION 1 AND OPTION 2 DO NOT MATCH**

This is printed when the answer to question (L) (OPTION 1) and the answer to question (L-1) (OPTION 2) do not go together as specified by Appendix E of GRAPH. Question (L) is again repeated.

****BOTH AXES CANNOT BE GREATER THAN W**

This is printed after one has specified the size of both the x axis and the y axis. The response to each must have been less than 50 or the question would have been repeated. However, one of the axes must be less than W (10.8 or 29.3, depending on the size of the paper) so that the page can be put on the paper.

****THE OBSERVED MAX & MIN ARE EQUAL FOR 1 AXIS**

Should default minimum and maximum values be specified for setting axes and the minimum and maximum be the same, then this diagnostic is printed, an ESCAPE RETURN generated, and control is returned to the plotting program. This essentially means that horizontal and vertical lines may be plotted only if non-default

axis limits are specified or the lines are plotted as an overlay. The line may tilt over its length by as little as one part in 10^6 and still get by this obstacle.

****FILE HAS BEEN CLOSED. NO MORE PLOTS IN THIS RUN.**

This diagnostic appears after question (N) is answered affirmatively. This is to remind the user that the only portion of PEPSUB still accessible is question (0).

****FILE WAS CLOSED ON LAST CALL.
NO MORE PLOTS ALLOWED.**

When only question (0) may be asked, this diagnostic is printed to explain to the user why questions (A) through (N) are not asked.

V. Instructions for Using BASIC-PEP

The instructions for using BASIC-PEP are much simpler than the instructions for using PEPSUB since PEPSUB has taken care of the options. There are really only three types of questions asked by BASIC-PEP. It operates much like PEPSUB in that it recognizes -2 as the default option and -1 as the escape option, meaning to stop the program. If it does not recognize the response to a question, it also repeats the question until it gets an acceptable response.

The first thing that BASIC-PEP does is read a flag as to whether or not any hard copy plot should be generated (as set by question (A) of PEPSUB). Then it reads through the file and writes the controls for each plot on a separate file. If an escape return has been used, the control section belonging to that plot is not saved. Then it clears the screen, prints out the number of normal returns and escape returns encountered and asks the following question

READY TO BEGIN PLOTTING?

When YES or -2 is responded, it clears the screen and places the first plot on the screen.

After each plot or overlay, there are two types of questions asked. (There are more than two different questions, but the

differences are easily understood when using the program.) The first type of question concerns whether or not the particular plot or overlay should be saved. (This type of question is not used if no plot can be generated on the plotter.) If the answer is YES, the plot or overlay will be saved. If the answer is NO or -2, the plot will not be saved.

The second type of question asks if the user is ready for the next plot or overlay. When BASIC-PEP receives an answer of YES or -2, it will go onto the next plot or overlay.

When all the plotting is finished, BASIC-PEP will clear the screen and inform the user of how many plots have been generated on paper. If some plots have been generated, it reminds the user of the job number. Then it displays a message saying that this is the end of this job. The user is in EXEC mode and can call another processor.

If one is attempting to get hard copy in a batch run, bypassing the PEP terminal, a simple procedure is possible. After the PEP card in the data deck (in response to question (0)), a series of cards saying YES in columns 1-3 should be entered. The number of such cards needed is $2 \cdot N + 1$ where N is the number of NEW and OVERLAY plots produced. Thus the deck structure would be:

•
•
•
PEP

YES

YES

•
•
•
YES

@FIN (or @BASIC etc.)

VI. Notes for Easier Usage

Although the previous explanations should be adequate as far as using the program is concerned, this section contains a few notes which should make usage less painful.

- (1) **Cost:** Since PEPSUB and BASIC-PEP do a lot of bookkeeping work for the user, they can get expensive. For this reason, they are designed to handle no more than 250 points. This means that they take less memory and run faster than if they were larger. Furthermore, the PEP screen can only handle about 200 points without giving redundant information. However, the user is encouraged to use no more points than necessary and to use the escape return sparingly since it requires handling by the computer for which the user gets no plot.
- (2) **Delay:** At certain times both programs, but especially BASIC-PEP, may apparently stop processing for a few seconds. This is usually due to the program being occupied with some internal task. There are two times when BASIC-PEP commonly stops for a short delay. The first is at the very beginning when it is reading through the input file. The second is observed whenever it is supposed to save a plot or overlay.

- (3) Options: A user can more easily get an idea of how the programs run by not using the options initially. Then when he is familiar with the default options, he is in better shape to choose options intelligently. It is usually less frustrating to go into a session with a good idea of what options one will use.
- (4) Screen blinking: At certain times, the screen will blink. This is expected and depends on the condition of the PEP (a good screen blinks less) and how busy the 1110 is (there are fewer blinks when it is not busy). The blinks apparently occur when the 1110 is purging the buffer space and there is a momentary break in instructions from the 1110.
- (5) Prior to running PEPSUB, BASIC-PEP must be on file in core image format. Loading BASIC-PEP, while different than loading a BASIC program, is no more difficult. A complete listing of BASIC-PEP along with all control cards properly sequenced is included as Appendix B-3. All that must be added to this deck is an @RUN card (with a \$10.00 cost limit) an @PASS card, and an @FIN card at the end, and BASIC-PEP will load itself.
- (6) An individual user may wish to "hard-wire" some of PEPSUB's options. Program modifications may be done as the user sees fit provided that the order in which

options are specified is not modified. In other words, the source of the value of an option or the default value may be changed, but the sequence of option specification must not be altered.

- (7) PEPSUB currently allows only 250 points to be plotted. To expand capabilities to 1000 points requires changes to both PEPSUB and BASIC-PEP. One thousand-point versions of the routines are available. The 1000-point version of PEPSUB is called PEPTHOU and the 1000-point version of BASIC-PEP is called BIGGER-PEP. PEPSUB may be turned into PEPTHOU independently by making the following changes:

- (a) Dimension X and Y arrays to 1000 points each.
- (b) Replace the number 250 in statements 9588 and 9634 with the number 1000 (see Appendix B-2).
- (c) Rewrite statement 9108 to read

9108 Let Z2\$='@XQT CHEMISTRY*WALTERS.BIGGER-PEP'

That's the easy part, and can be done "on the fly" in BASIC. BIGGER-PEP, however, must be created in a separate batch run. The easiest procedure is to load the BIGGER-PEP deck into the computer (an appropriate deck is available). The differences between BASIC-PEP and BIGGER-PEP are listed below. Numbers at the start of each line are the numbers at the far left of the

listing in Appendix B-3, not FORTRAN line numbers. Lines should be modified to read:

Page PM 1-8:

00013 DIMENSION XDATA (1000), YDATA (1000),
 XSAVE (5, 1014), YSAVE (5, 1014)

(Note that only one NEW plot and four OVERLAY
plots may be made in a group; more overlays
would be allowed if XSAVE and YSAVE were
dimensioned 6 or 7 by 1014 instead of 5 by 1014.

This number was chosen in a trade-off between
cost and capabilities.)

00205 XSAVE (1, 1001) = 2
00206 XSAVE (1, 1002) = -9
00207 XSAVE (1, 1003) = 0
00218 XSAVE (KP, 1001) = IPOINT
00219 XSAVE (KP, 1002) = ISYMBL
00220 XSAVE (KP, 1003) = LINE
00330 IPOINT = XSAVE (1, 1001)
00331 ISYMBL = XSAVE (1, 1002)
00333 LINE = XSAVE (1, 1003)
00343 IPOINT = XSAVE (J, 1001)
00347 ISYMBL = XSAVE (J, 1002)
00349 LINE = XSAVE (J, 1003)

Page PM-11:

00002 DIMENSION ISAVE (10, 1014), INBUF (10)

Page PM-12:

00001 @MAP,I CHEMISTRY*WALTERS//01.BIGGER-PEP

Cost is directly proportional to the number of plotable points, so use discretion when considering using the enlarged plotting package.

Appendix B-1

VARIABLES USED BY PEPSUB

Name	Type	Description
X	Numeric Array	Used to pass abscissa values from the calling program to PEPSUB.
Y	Numeric Array	Used to pass ordinate values from the calling program to PEPSUB.
Z1	Numeric	Keeps track of how many times PEPSUB has been called. This information is also used as a flag.
Z2	Numeric	Contains the maximum size of the plot paper. It is also used to check whether plot can be saved by this run.
Z3	Numeric	Contains a numerical code representing the plot type as follows: 1 NEW 2 OVERLAY 3 NONE It is used as a flag several times during each call to PEPSUB.
Z4	Numeric	Contains the type of the last completed call to PEPSUB. It is also used temporarily when accepting data.
Z5	Numeric	Used in accepting data.

Name	Type	Description
Z6	Numeric	Used in checking page options and size and in accepting data.
Z7	Numeric	Used in accepting the line code, minimum values, and size of y axis. It is also used in checking the page options.
Z8	Numeric	Used in accepting symbol code and maximum values and for checking the page options.
Z9	Numeric	Contains, with Z3, information about the status of this call to PEPSUB. Its status can change, while the status of Z3 is fixed throughout the call.
Z\$	String Array	Contains the page option.
Z\$	String	Accepts input for plot type and options.
Z1\$	String	Used as string format.
Z2\$	String	Accepts input for most questions requesting string input.
Z3\$	String	Used as numeric format.
Z4\$	String	Used in checking page options and whether or not plot can be saved.
Z5\$	String	Holds information concerning paper size and liquid ink option.
Z6\$	String	Accepts input as to whether or not liquid ink should be used.
Z7\$	String	Serves as flag as to whether or not any plot will be generated.

Appendix B-2

LISTING OF PEPSUB

PS-1

```

1 9000 *
2 9002 'ENTER PEP SUBROUTINE'
3 9004 *
4 9006 DATA HALF,HALF,THFULL,BHFULL,THFULL,BHFULL,FULL,FULL,THFULL
5 9008 DATA THFULL,FULL,FULL,FULL,FULL,DOUBLE,DOUBLE,DOUBLE,LHDBLE
6 9010 DATA RHDBLE,LHDBLE,RHDBLE,RHDBLE,RHDBLE,LHDBLE,LHDBLE,DOUBLE
7 9012 DATA NORMAL,TRNSP,NORMAL,NORMAL,BIND,BIND,NORMAL,BIND
8 9014 DATA TRNSP,TRNSP,TRBIND,TRBIND,TRNSP,TRBIND,TRNSP,NORMAL,TRBIND
9 9016 DATA NORMAL,NORMAL,BIND,BIND,TRNSP,TRBIND,TRNSP,LHDBLE,DOUBLE
10 9018 IF Z1=0 THEN 9114
11 9020 LET Z1=0
12 9022 LET Z1$='XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX'
13 9024 LET Z1$='0.0000000000 0.0000000000'
14 9026 DIM Z$(52)
15 9028 'A) SHOULD CALCOMP PLOTTER CAPABILITY BE TURNED ON?'
16 9030 INPUT Z1
17 9032 IF Z1$=-1 THEN 9718
18 9034 IF Z1$=-2 THEN LET Z2$='YES'
19 9036 IF Z1$='NO' OR Z2$='YES' THEN 9042
20 9038 *
21 9040 GO TO 9038
22 9042 IF Z1$='NO' THEN LET Z7$=' ' ELSE LET Z7$='QGSP,PT'
23 9044 IF Z1$='NO' THEN 9078
24 9046 *
25 9048 'B) PAPER SIZE ('LARGE' OR 'SMALL')?'
26 9050 INPUT Z1
27 9052 IF Z1$=-1 THEN 9718
28 9054 LET Z1=0
29 9056 IF Z1$='LARGE' THEN LET Z2=29.3
30 9058 IF Z1$='SMALL' THEN LET Z2=10.8
31 9060 IF Z1$=-2 THEN LET Z2=10.8
32 9062 IF Z1=0 THEN 9046
33 9064 *
34 9066 'C) LIQUID INK ('YES' OR 'NO')?'
35 9068 INPUT Z1
36 9070 IF Z1$=-2 THEN LET Z6$='NO'
37 9072 IF Z1$=-1 THEN 9718
38 9074 IF Z1$='NO' OR Z6$='YES' THEN 9078
39 9076 GO TO 9064
40 9078 *
41 9080 MAY READ Z1
42 9082 OPEN PLOT FOR SYMBOLIC OUTPUT AS FILE 9
43 9084 LET Z9=0
44 9086 IF Z7$= ' ' THEN PRINT ON 9 IN IMAGE Z1$:Z7$
45 9088 IF Z7$= ' ' THEN 9108
46 9090 IF Z2=10.8 AND Z6$='NO' THEN 9108
47 9092 IF Z6$='NO' THEN 9100
48 9094 IF Z2=10.8 THEN 9104
49 9096 LET Z5$='PLOTTER PAPER/30,PEN/LIQ'
50 9098 GO TO 9106
51 9100 LET Z5$='PLOTTER PAPER/30'
52 9102 GO TO 9106
53 9104 LET Z5$='PLOTTER PEN/LIQ'
54 9106 PRINT ON 9 IN IMAGE Z1$:Z5$
55 9108 LET Z2$='EXOT CHEMISTRY*WALTERS.BASIC-PEP'
56 9110 PRINT ON 9 IN IMAGE Z1$:Z2$
57 9112 PRINT ON 9 IN IMAGE 'XX.XXXX':Z2

```

75-2

```

58 9114 LET Z1=Z1+1
59 9116 LET X5=0
60 9118 IF Z4=5 THEN 9736
61 9120 '
62 9122 LET Z9=0
63 9124 'D) TYPE OF PLOT: NEW, OVERLAY, OR NONE';
64 9126 INPUT Z5
65 9128 IF Z5='-1' THEN LET Z9=-1
66 9130 IF Z9=-1 AND Z4=>1 THEN LET Z3=2
67 9132 IF Z9=-1 THEN PRINT ON 9 IN IMAGE Z1: 'NEW PLOT'
68 9134 IF Z9=-1 THEN 9218
69 9136 IF Z5='-2' THEN LET Z5='NEW'
70 9138 LET Z3=0
71 9140 IF Z5='NEW' THEN Z3=1
72 9142 IF Z5='OVERLAY' THEN LET Z3=2
73 9144 IF Z5='NONE' THEN LET Z3=3
74 9146 IF Z3=0 THEN 9118
75 9148 IF Z3=2 AND Z4=2 THEN 9162
76 9150 IF Z3<>2 THEN 9162
77 9152 IF Z3=2 AND Z4=1 THEN 9162
78 9154 '
79 9156 '***YOU CANNOT DO AN OVERLAY WITHOUT AT LEAST'
80 9158 ' ONE NEW PLOT'
81 9160 GO TO 9118
82 9162 LET Z9=Z3
83 9164 ON Z3 GO TO 9170,9166,9664
84 9166 PRINT ON 9 IN IMAGE Z1: 'OVERLAY'
85 9168 GO TO 9276
86 9170 PRINT ON 9 IN IMAGE Z1: 'NEW PLOT'
87 9172 '
88 9174 'E) OPTIONS';
89 9176 INPUT Z5
90 9178 IF Z5='-1' THEN LET Z9=-1
91 9180 IF Z5='-1' THEN 9218
92 9182 IF Z5='-2' THEN 9192
93 9184 IF Z5='NO' THEN 9192
94 9186 IF Z5<>'YES' THEN 9172
95 9188 LET Z9=1
96 9190 GO TO 9196
97 9192 LET Z9=0
98 9194 REM -- TITLE --
99 9196 IF Z9<=0 THEN 9218
100 9198 '
101 9200 ' F) TITLE';
102 9202 INPUT Z5
103 9204 IF Z5='-2' THEN 9218
104 9206 IF Z5='-1' THEN LET Z9=-1
105 9208 IF Z5='-1' THEN 9218
106 9210 IF Z5='-3' THEN LET Z9=0
107 9212 IF Z5='-3' THEN 9218
108 9214 PRINT ON 9 IN IMAGE Z1:Z5
109 9216 GO TO 9226
110 9218 PRINT ON 9 IN IMAGE 'XXXXX': 'PLOT';
111 9220 PRINT ON 9 IN IMAGE 'XXXXX': Z1
112 9222 REM -- LABEL FOR X-AXIS --
113 9224 IF Z9<=0 THEN 9246
114 9226 '

```

PS-3

```

115 9228 ' G) X AXIS LABEL'
116 9230 INPUT Z2$
117 9232 IF Z2$='-3' THEN LET Z9=0
118 9234 IF Z2$='-2' THEN 9246
119 9236 IF Z2$='-3' THEN 9246
120 9238 IF Z2$='-1' THEN LET Z9=-1
121 9240 IF Z2$='-1' THEN 9246
122 9242 PRINT ON 9 IN IMAGE Z1$:Z2$
123 9244 GO TO 9252
124 9246 PRINT ON 9 IN IMAGE Z1$: 'X AXIS'
125 9248 IF Z9<=0 THEN 9270
126 9250 REM -- Y-AXIS LABEL --
127 9252 '
128 9254 ' H) Y AXIS LABEL'
129 9256 INPUT Z2$
130 9258 IF Z2$='-1' THEN LET Z9=-1
131 9260 IF Z2$='-3' THEN LET Z9=0
132 9262 IF Z2$='-1' THEN 9270
133 9264 IF Z2$='-2' OR Z2$='-3' THEN 9270
134 9266 PRINT ON 9 IN IMAGE Z1$:Z2$
135 9268 GO TO 9276
136 9270 PRINT ON 9 IN IMAGE Z1$: 'Y AXIS'
137 9272 IF Z9<=0 THEN 9300
138 9274 REM -- SYMBOL AT EACH DATA POINT --
139 9276 '
140 9278 ' I) SYMBOL CODE'
141 9280 INPUT Z8
142 9282 IF Z8>15 THEN 9276
143 9284 IF Z8=-1 THEN LET Z9=-1
144 9286 IF Z8=-3 THEN LET Z9=0
145 9288 IF Z8=-1 THEN 9300
146 9290 IF Z8=-2 OR Z8=-3 THEN 9300
147 9292 IF Z8<0 THEN 9276
148 9294 IF Z8<>INT(Z8) THEN 9276
149 9296 PRINT ON 9 IN IMAGE 'ZX':Z8
150 9298 GO TO 9306
151 9300 PRINT ON 9 IN IMAGE 'ZX': '-9'
152 9302 IF Z9<=0 THEN 9340
153 9304 REM -- LINE TO CONNECT DATA POINTS --
154 9306 '
155 9308 ' J) DASH CODE'
156 9310 INPUT Z7
157 9312 IF Z7>23 THEN 9306
158 9314 IF Z7=-1 THEN LET Z9=-1
159 9316 IF Z7=-1 THEN 9340
160 9318 IF Z8=-2 AND Z7=0 THEN 9330
161 9320 IF Z7=-3 THEN LET Z9=0
162 9322 IF Z7=-2 OR Z7=-3 THEN 9340
163 9324 IF Z7<0 THEN 9306
164 9326 IF Z7<>INT(Z7) THEN 9306
165 9328 GO TO 9336
166 9330 '
167 9332 '** BUT YOU HAVE NO SYMBOL EITHER'
168 9334 GO TO 9306
169 9336 PRINT ON 9 IN IMAGE 'ZX':Z7
170 9338 GO TO 9348
171 9340 PRINT ON 9 IN IMAGE 'ZX': '-9'

```

PS-4

```

172 9342 IF Z9<0 AND Z3=2 THEN 9638
173 9344 IF Z9<=0 AND Z3<>2 THEN 9386
174 9346 REM -- MAXIMUM AND MINIMUM --
175 9348 IF Z3=2 THEN 9554
176 9350 ' '
177 9352 ' K-1) MAXIMUM (X AXIS) '
178 9354 INPUT Z8
179 9356 IF Z8=-1 THEN LET Z9=-1
180 9358 IF Z8=-1 THEN 9386
181 9360 IF Z8=-3 THEN LET Z9=0
182 9362 IF Z8=-3 OR Z8=-2 THEN 9386
183 9364 ' '
184 9366 ' K-2) MINIMUM (X AXIS) '
185 9368 INPUT Z7
186 9370 IF Z7=-1 THEN LET Z9=-1
187 9372 IF Z7=-1 THEN 9386
188 9374 IF Z7=-3 THEN LET Z9=0
189 9376 IF Z7=-3 OR Z7=-2 THEN 9386
190 9378 IF Z7=28 THEN PRINT '** THE MAX & MIN CANNOT BE EQUAL'
191 9380 IF Z7=28 THEN 9350
192 9382 PRINT ON 9 IN IMAGE Z38: Z7,Z8
193 9384 GO TO 9392
194 9386 PRINT ON 9 IN IMAGE 'XXX': '0 0'
195 9388 GO TO 9434
196 9390 REM -- MAX & MIN ON Y AXIS --
197 9392 ' '
198 9394 LET Z4=0
199 9396 ' K-3) MAXIMUM (Y AXIS) '
200 9398 INPUT Z8
201 9400 IF Z8=-1 THEN LET Z9=-1
202 9402 IF Z8=-1 THEN 9434
203 9404 IF Z8=-3 THEN LET Z9=0
204 9406 IF Z8=-3 OR Z8=-2 THEN 9434
205 9408 ' '
206 9410 ' K-4) MINIMUM (Y AXIS) '
207 9412 INPUT Z7
208 9414 IF Z7=-1 THEN LET Z9=-1
209 9416 IF Z7=-1 THEN 9434
210 9418 IF Z7=-3 THEN LET Z9=0
211 9420 IF Z7=-3 OR Z7=-2 THEN 9434
212 9422 IF Z7<>28 THEN 9430
213 9424 ' '
214 9426 '** THE MAX & MIN CANNOT BE EQUAL'
215 9428 GO TO 9392
216 9430 PRINT ON 9 IN IMAGE Z38: Z7,Z8
217 9432 GO TO 9440
218 9434 PRINT ON 9 IN IMAGE 'XXX': '0 0'
219 9436 LET X5=1
220 9438 REM -- PAGE SIZE --
221 9440 IF Z7= ' ' AND Z9>0 THEN LET Z9=0
222 9442 IF Z9<=0 THEN 9494
223 9444 ' '
224 9446 ' L) SPECIAL PAGE CODE '
225 9448 INPUT Z28
226 9450 IF Z28='1' OR Z28='-2' OR Z28='-3' THEN 9494
227 9452 IF Z28='NUMBER' THEN 9502
228 9454 FOR Z4=1 TO 24

```

IS-5

```

229 9454 LET Z7=Z6
230 9458 IF Z2#Z1(Z6) THEN 9446
231 9460 NEXT Z6
232 9462 GO TO 9444
233 9464 LET Z6=0
234 9466 '
235 9468 ' L-1) SECOND OPTION'
236 9470 INPUT Z4
237 9472 FOR Z8=Z7 TO Z6
238 9474 IF Z4#Z1(Z8+Z6) AND Z2#Z1(Z8) THEN 9486
239 9476 NEXT Z8
240 9478 IF Z4#'-2' OR Z4#'-1' OR Z4#'-3' THEN 9494
241 9480 '
242 9482 '** THE OPTIONS 'Z2#' AND 'Z4#' DO NOT MATCH'
243 9484 GO TO 9444
244 9486 PRINT ON 9 IN IMAGE Z1:'SPECIAL CODES'
245 9488 PRINT ON 9 IN IMAGE Z1:Z1(Z8)
246 9490 PRINT ON 9 IN IMAGE Z1:Z1(Z8+Z6)
247 9492 GO TO 9534
248 9494 PRINT ON 9 IN IMAGE Z1:'NUMBER'
249 9496 PRINT ON 9 IN IMAGE Z3:Z2,Z2
250 9498 IF Z2#'-1' THEN LET Z9=-1
251 9500 GO TO 9552
252 9502 PRINT ON 9 IN IMAGE Z1:'NUMBER'
253 9504 '
254 9504 ' L-2) SIZE OF X AXIS'
255 9508 INPUT Z4
256 9510 IF Z4=-1 THEN LET Z9=-1
257 9512 IF Z4=-1 THEN 9548
258 9514 IF Z4=-2 THEN 9548
259 9516 IF Z4<0 THEN 9504
260 9518 IF Z4>0 THEN 9504
261 9520 '
262 9522 ' L-3) SIZE OF Y AXIS'
263 9524 INPUT Z7
264 9526 IF Z7=-1 THEN LET Z9=-1
265 9528 IF Z7=-1 THEN 9548
266 9530 IF Z7=-2 THEN 9548
267 9532 IF Z7>0 THEN 9520
268 9534 IF Z7<0 THEN 9520
269 9536 IF Z7<=Z2 OR Z6<=Z2 THEN 9544
270 9538 '
271 9540 '** BOTH AXES CANNOT BE GREATER THAN 'Z2
272 9542 GO TO 9504
273 9544 PRINT ON 9 IN IMAGE Z3:Z6,Z7
274 9546 GO TO 9554
275 9548 LET Z6=Z7=Z2
276 9550 PRINT ON 9 IN IMAGE Z3:Z6,Z7
277 9552 IF Z9<0 THEN 9638
278 9554 '
279 9556 '(M) DATA FROM PEP OR X & Y ARRAYS'
280 9558 '
281 9560 ' ANSWER ('PEP' OR 'XY')'
282 9562 INPUT Z2
283 9564 IF Z2#'-1' THEN LET Z9=-1
284 9566 IF Z2#'-1' THEN 9638
285 9568 IF Z2#PEP THEN 9608

```

PS-6

```

286 09570 IF Z2$='XY' THEN 9576
287 09572 GO TO 9558
288 09574 REM -- INPUT FROM X & Y ARRAYS --
289 09576 ' '
290 09578 ' M-2) HOW MANY POINTS';
291 09580 INPUT Z4
292 09582 IF Z4=-1 THEN LET Z9=-1
293 09584 IF Z4=-1 THEN 9638
294 09586 IF Z4<1 THEN 9576
295 09588 IF Z4>250 THEN 9576
296 09590 IF INT(Z4)/Z4 THEN 9576
297 09592 IF X5=1 THEN GOSUB 9770
298 09594 IF Z9<-1 THEN PRINT ON 9 IN IMAGE Z1$:'DATAFOLLOWS' ELSE 9638
299 09596 FOR Z5=1 TO Z4
300 09598 PRINT ON 9 IN IMAGE Z3$:X(Z5),Y(Z5)
301 09600 NEXT Z5
302 09602 LET Z4=Z4+1
303 09604 GO TO 9640
304 09606 REM -- INPUT FROM THE TTY --
305 09608 PRINT ON 9 IN IMAGE Z1$:'DATAFOLLOWS'
306 09610 LET Z4=0
307 09612 ' '
308 09614 ' M-1) INPUT THE COORDINATES BY PAIRS'
309 09616 ' '
310 09618 LET Z4=Z4+1
311 09620 'POINT 'Z4$' = '
312 09622 INPUT Z5,Z6
313 09624 IF Z4=1 AND X5=1 THEN GOSUB 9746 ELSE IF X5=1 THEN GOSUB 9752
314 09626 IF Z5=-1 AND Z6=-1 THEN LET Z9=-1
315 09628 IF Z5=-2 AND Z6=-2 THEN 9640
316 09630 IF Z9=-1 THEN 9644
317 09632 PRINT ON 9 IN IMAGE Z3$:Z5,Z6
318 09634 IF Z4>250 THEN 9644
319 09636 GO TO 9618
320 09638 PRINT ON 9 IN IMAGE Z1$:'EARLY ESCAPE'
321 09640 IF Z4<3 THEN LET Z9=-1
322 09642 IF Z9<-1 AND X5=1 THEN GOSUB 9762
323 09644 PRINT ON 9 IN IMAGE 'XXXXX':'-1 -1'
324 09646 IF Z9=-1 THEN PRINT ON 9 IN IMAGE Z1$:'NODATA'
325 09648 IF Z9<-1 THEN PRINT ON 9 IN IMAGE Z1$:'ENDOFDATA'
326 09650 LET Z4=0
327 09652 REM -- END OF ONE PLOT --
328 09654 REM -- CHECK THE STATUS OF THE PLOT --
329 09656 REM -- RETURN FOR 'NEW' --
330 09658 IF Z9<-1 THEN LET Z4=Z3
331 09660 IF Z9=-1 AND Z3=2 THEN LET Z4=1
332 09662 IF Z2$='-1' THEN 9718
333 09664 PRINT ' '
334 09666 'N) DONE WITH PLOTTING FOR THIS RUN';
335 09668 INPUT Z2$
336 09670 IF Z2$='YES' OR Z2$='Y' THEN 9684
337 09672 IF Z2$='-3' OR Z2$='-2' OR Z2$='NO' THEN 9676
338 09674 IF Z2$='-1' OR Z2$='N' THEN 9676 ELSE 9664
339 09676 ' '
340 09678 'NORMAL RETURN'
341 09680 ' '
342 09682 RETURN

```

Z3-7

```

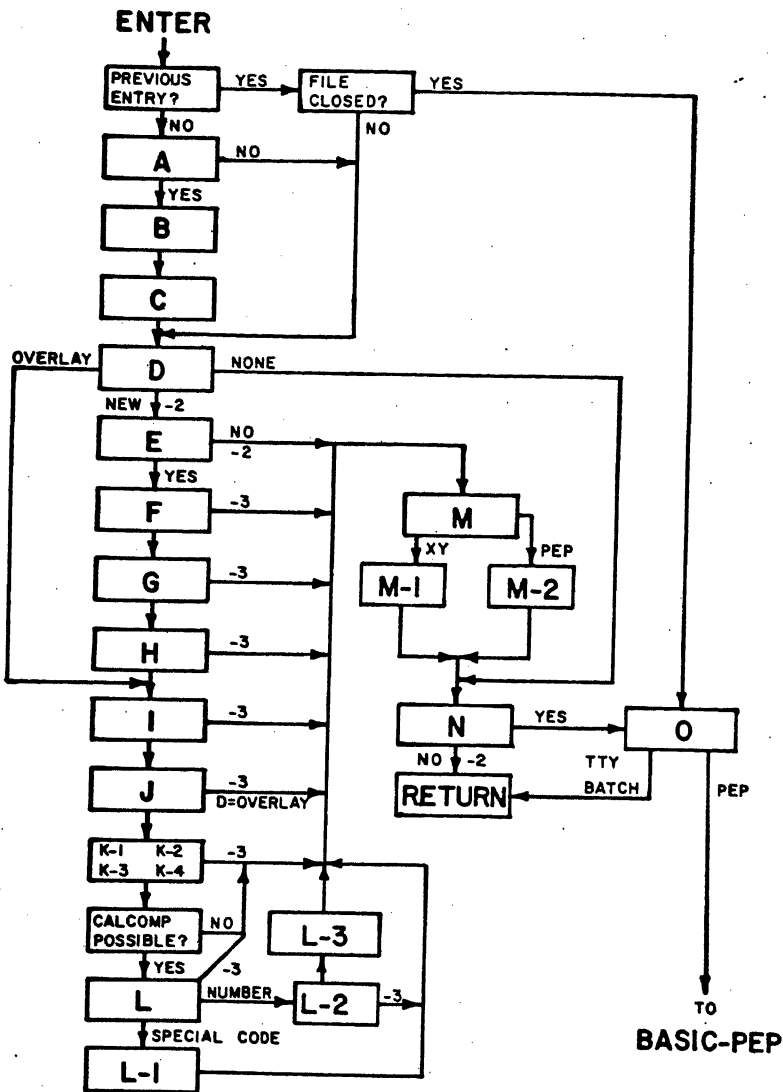
343      9484 REM      -- CLOSE FILE AND TERMINATE PLOTTING --
344      9486 LET Z3='EOF'
345      9488 PRINT ON 9 IN IMAGE Z1:Z2
346      9490 CLOSE 9
347      9492 ' '
348      9494 '** FILE HAS BEEN CLOSED. NO MORE PLOTS ALLOWED IN THIS RUN.'
349      9496 ' '
350      9498 '0' TO PLOT ON THE PEP TERMINAL IMMEDIATELY, TYPE 'PEP'
351      9700 ' OTHERWISE TYPE 'TTY' OR 'BATCH'
352      9702 INPUT Z3
353      9704 PRINT ' '
354      9706 IF Z3='PEP' THEN 9710
355      9708 IF Z3='TTY' OR Z3='BATCH' THEN 9728 ELSE 9698
356      9710 'EXIT FROM BASIC'
357      9712 EXEC 'QASG,A PLOT. ' '
358      9714 EXEC 'QADD,P PLOT. ' '
359      9716 STOP
360      9718 ' '
361      9720 'ESCAPE RETURN'
362      9722 ' '
363      9724 IF Z3<>1 THEN LET Z4=Z3 ELSE LET Z4=0
364      9726 RETURN
365      9728 'NO EXIT FROM BASIC'
366      9730 'FURTHER CALLS TO PEPSUB WILL NOT PERMIT PLOTTING.'
367      9732 LET Z4=5
368      9734 RETURN
369      9736 '** FILE WAS CLOSED ON THE LAST CALL.'
370      9738 ' NO MORE PLOTS ALLOWED.'
371      9740 PRINT ' '
372      9742 GO TO 9698
373      9744 REM ----- CHECK FOR MAX & MIN FROM M-1 -----
374      9746 LET X6=X7=Z5
375      9748 LET X8=X9=Z6
376      9750 RETURN
377      9752 IF Z5<X6 THEN LET X6=Z5
378      9754 IF Z5>X7 THEN LET X7=Z5
379      9756 IF Z6<X8 THEN LET X8=Z6
380      9758 IF Z6>X9 THEN LET X9=Z6
381      9760 RETURN
382      9762 IF X6=X7 OR X8=X9 THEN LET Z9=-1
383      9764 IF Z9=-1 THEN GOSUB 9796
384      9766 RETURN
385      9768 REM ----- CHECK FOR MAX & MIN FROM M-2 -----
386      9770 LET X6=X7=X(1)
387      9772 LET X8=X9=Y(1)
388      9774 FOR Z5=2 TO Z4
389      9776 IF X(Z5)<X6 THEN LET X6=X(Z5)
390      9778 IF X(Z5)>X7 THEN LET X7=X(Z5)
391      9780 IF Y(Z5)<X8 THEN LET X8=Y(Z5)
392      9782 IF Y(Z5)>X9 THEN LET X9=Y(Z5)
393      9784 NEXT Z5
394      9786 IF X6=X7 OR X8=X9 THEN LET Z9=-1
395      9788 IF Z9<-1 THEN 9792
396      9790 GOSUB 9796
397      9792 RETURN
398      9794 REM ----- PRINT OUT PROBLEMS WITH MAX & MIN -----
399      9796 ' '

```


75-3

```
400 9798 '** THE OBSERVED MAX & MIN ARE EQUAL FOR 1 AXIS'
401 9800 ' '
402 9802 'X MIN = 'IX6
403 9804 'X MAX = 'IX7
404 9806 'Y MIN = 'IX8
405 9808 'Y MAX = 'IX9
406 9810 ' '
407 9812 RETURN
408 99999END
```

PEPSUB · FLOWCHART



Appendix B-3

LISTING OF BASIC-PEP

To load BASIC-PEP, the program as listed on pages PM-1 through PM-12 may be loaded directly as given, with the only additional cards needed being an @RUN card, an @PASS card, and an @FIN card (the first two at the beginning of the deck and the last one at the end). In order to obtain the listing, it was necessary to add some cards to the program as it is to be loaded; the statements which are actually part of the program are sequenced starting with a line number 1 for each of the four subroutines. So to create the correct deck, use only the sequentially numbered statements, and ignore the @HDG and other extraneous lines.

PM-1

PRY,S LISTER,PEP-MAIN
URPUR-RACC 4-06 RL1612 07/24-23:33:10

893402639=LISTER(0),PEP-MAIN

```

1  BFOR,I,PEP-MAIN
2  C
3  C
4  C
5  C
6  C
7  C
8  C
9  C
10 C
11 C
12 C
13 C
14 C
15 C
16 C
17 C
18 C
19 C
20 C
21 C
22 C
23 C
24 C
25 C
26 C
27 C
28 C
29 C
30 C
31 C
32 C
33 C
34 C
35 C
36 C
37 C
38 C
39 C
40 C
41 C
42 C
43 C
44 C
45 C
46 C
47 C
48 C
49 C
50 C
51 C
52 C
53 C

```

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DIMENSION INBUF(10),ITITLE(41),IXLABL(41),IYLABL(41)

DIMENSION XDUP(2),YDUP(2)

DIMENSION XDATA(250),YDATA(250),XSAVE(5,264),YSAVE(5,264)

COMMON/TRAN/XSAVE,YSAVE,INBUF,IJESCAP,IJKEEP

READ(5,*,END=1501) XI

IPLTST=6HNPLOT

IFCXX.LT.1,IPLTST=6HNGPLOT

C LOAD THE DATA ONTO SCRATCH FILE 2

CALL WRTFI

IPLTG=0

CALL GSPSET(6HGRPNCS,120,SHIMROT)

CALL PFRMFD

CALL PURGBF

PRINT 899,IJKEEP

PRINT 900,IJESCAP

10 CONTINUE

CALL WRTXT(0,5,*,*READY TO BEGIN PLOTTINGSQUESS SS*,14,0,*,*)

CALL PURGBF

READ(5,901,END=1500)KSAVPL

IF(KSAVPL.EQ."YES".OR.KSAVPL.EQ."-2") GO TO 12

IF(KSAVPL.EQ."STOP".OR.KSAVPL.EQ."-1") GO TO 1500

CALL POSITN(0,5,15)

CALL PURGBF

CALL HYERAS(33)

GO TO 10

12 CONTINUE

KSAVPL=0

C CHECK THE STATUS OF THE PLOT

READ(2,901,END=1500) INBUF

CONTINUE

IF(INBUF(1).EQ."NEW PI".AND.INBUF(2).EQ."0") GO TO 101

IF(INBUF(1).NE.1H.OR.INBUF(2).NE.1H) GO TO 91

1500 CONTINUE

C END OF RUN

CALL PFRMFD

CALL PURGBF

CALL EXTRAN(6,"FREE 2")

IF(KASG3.EQ.1) CALL EXTRAN(6,"FREE 3")

CALL URPRID(IRUNID)

IF(IPLTG.GT.0) PRINT 907,IPLTG

PM-2

```

54      IF(IPL0TG.EQ.0) PRINT 908
55      IF(IPL0TG.GT.0) PRINT 909,IPUN10
56      PRINT 910
57      STOP
58      91      CONTINUE
59      PRINT 903
60      GO TO 1500
61      101     CONTINUE
62      C
63      C STATUS="NEW PLOT"
64      C
65      READ(2,901,END=1501) INBUF
66      C TITLE
67      CALL SUBCHR(INBUF,ITITLE)
68      READ(2,901,END=1501) IABUF
69      C X-AXIS LABEL
70      CALL SUBCHR(INBUF,IXLABL)
71      READ(2,901,END=1501) INBUF
72      C Y-AXIS LABEL
73      CALL SUBCHR(INBUF,IYLABL)
74      C SYMBOL AT EACH POINT
75      READ(2,-,END=1501) ISYMBL
76      IF(ISYMBL.EQ.-9) ISYMBL=4HNONE
77      C LINE CODE
78      READ(2,-,END=1501) LINE
79      IF(LINE.EQ.0) LINE=5HBLANK
80      IF(LINE.EQ.-9) LINE=5HSOLID
81      C X-AXIS MAX AND MIN
82      READ(2,-,END=1501) XMIN,XMAX
83      C Y-AXIS MAX AND MIN
84      READ(2,-,END=1501) YMIN,YMAX
85      IX=0
86      IY=0
87      IF(ABS(XMAX).LT.1.E-6.AND.ABS(XMIN).LT.1.E-6) IX=1
88      IF(ABS(YMIN).LT.1.E-6.AND.ABS(YMAX).LT.1.E-6) IY=1
89      IPRE=0
90      IF(IX.EQ.1.OR.IY.EQ.1) GO TO 112
91      IPRE=1
92      XBUN(1)=XMIN
93      XBUN(2)=XMAX
94      YBUN(1)=YMIN
95      YBUN(2)=YMAX
96      112     CONTINUE
97      C PAGE SIZE
98      READ(2,901,END=1501) INBUF
99      IF(INBUF(1).EQ."NUMBER") GO TO 121
100     READ(2,901,END=1501) PGWID
101     READ(2,901,END=1501) PGHTE
102     GO TO 122
103     121     CONTINUE
104     READ(2,-,END=1501) PGWID,PGHTE
105     122     CONTINUE
106     C INPUT DATA
107     READ(2,901,END=1501) INBUF
108     IF(INBUF(1).EQ."DATAFO".AND.INBUF(2).EQ."LLOWS ") GO TO 131
109     PRINT 905
110     GO TO 1500

```

PM-3

```

111      131  CONTINUE
112      IPOINT=0
113      141  CONTINUE
114      READ(2,-,END=1501) XX,YY
115      143  CONTINUE
116      YCHECK=YY+1
117      YCHECK=YY+1.
118      IF(ABS(XCHECK).LT.1.E-6.AND.ABS(YCHECK).LT.1.E-6) GO TO 132
119      IPOINT=IPOINT+1
120      XDATA(IPOINT)=XX
121      YDATA(IPOINT)=YY
122      GO TO 141
123      132  CONTINUE
124      READ(2,901,END=1501) INBUF
125      IF(INBUF(1).EQ."ENDED".AND.INBUF(2).EQ."ATA") GO TO 151
126      IPOINT=IPOINT+1
127      XDATA(IPOINT)=XX
128      YDATA(IPOINT)=YY
129      BACKSPACE 2
130      READ(2,-) XX,YY
131      GO TO 141
132      151  CONTINUE
133      READ(2,901,END=1505) INBUF
134      IOSTAT=2
135      IF(INBUF(1).EQ."NEW PL".AND.INBUF(2).EQ."OT") IOSTAT=1
136      1503  CONTINUE
137      CALL ABSOR6
138      CALL PAGE(10,,10,,6HNORMAL,4HNONE)
139      CALL FRAME(10,,8,10,,10,,)
140      CALL SHCHG(1,1,1,1,1)
141      IF(IPLST.EQ.1) GO TO 161
142      C DO A GRAPH
143      CALL GRAPH(XDATA,1,YDATA,1,IPOINT,1,SYMBL,LINE,IXLABL,IYLABL,1,
144      .,ITITLE,6HPREDEF,4HNULL)
145      GO TO 1101
146      161  CONTINUE
147      C DO A GRAPH WITH A PREDEFINED MAX & MIN
148      CALL GRAPH(XDUM,1,YDUM,1,2,4HNONE,5HBLANK,IXLABL,IYLABL,1,
149      .,ITITLE,6HPREDEF,4HNULL)
150      CALL GRAPH(XDATA,5HSCAL1,YDATA,5HSCAL1,IPOINT,1,SYMBL,LINE)
151      1101  CONTINUE
152      CALL FRAME(10,,10,,10,,)
153      CALL PURGBF
154      IF(IPLST.EQ."NOPLOT") GO TO 1110
155      CALL WRTXT(10,,7,"SAVE PLOTSQUESS",14,0,.03)
156      CALL PURGBF
157      READ(5,901,END=1500) KSAVPL
158      IF(KSAVPL.EQ."NO".OR.KSAVPL.EQ."-2") GO TO 1110
159      IF(KSAVPL.EQ."YES") GO TO 1105
160      IF(KSAVPL.EQ."STOP".OR.KSAVPL.EQ."-1") GO TO 1500
161      CALL POSITN(10,,85)
162      CALL PURGBF
163      CALL MYERAS(3)
164      GO TO 1101
165      1105  CONTINUE
166      IF(10STAT.EQ.2) GO TO 1110
167      C PLOT ON PLOTTER

```

PM-4

```

168 CALL GSPSET(SHPLTTR,4,NONE,SHIMNDT)
169 IPLOTG=IPLOTG+1
170 IF(IPRE.EQ.1) GO TO 1106
171 CALL GRAPH(XDATA,1,YDATA,1,IPOINT,ISYMBL,LINE,IXLABL,IYLABL,2,
172 -ITITLE,PGEID,PWHITE)
173 GO TO 1107
174 1106 CONTINUE
175 CALL GRAPH(XDUR,1,YDUR,1,2,4,NONE,SHBLANK,IXLABL,IYLABL,2,
176 -ITITLE,PGEID,PWHITE)
177 CALL GRAPH(XDATA,SHSCAL1,YDATA,SHSCAL1,IPOINT,ISYMBL,LINE)
178 1107 CONTINUE
179 CALL GSPSET(ANGRMS,120,SHIMNDT)
180 1110 CONTINUE
181 IF(MSTOP.EQ.1) CALL WRTXT(0,...5,"READY TO QUIT SQUESS SS",.14,0,.
182 -3)
183 IF(MSTOP.EQ.0.AND.IOSTAT.EQ.1)
184 -CALL WRTXT(0,...5,"READY FOR NEXT PLOTSQUESS SS",.14,0,.0)
185 IF(MSTOP.EQ.1.AND.IOSTAT.EQ.2)
186 -CALL WRTXT(0,...5,"READY FOR OVERLAYSQUESS SS",.14,0,.0)
187 CALL PURGEF
188 READ(5,901,END=1500)KREADY
189 IF(KREADY.EQ."STOP".OR.KREADY.EQ."-1") GO TO 1500
190 IF(KREADY.EQ."YES".OR.KREADY.EQ."-2") GO TO 1112
191 CALL POSTYNG(.65)
192 CALL PURGEF
193 CALL MYERAS(3)
194 GO TO 1110
195 1112 CONTINUE
196 IF(MSTOP.EQ.1) GO TO 1500
197 IF(IOSTAT.EQ.1) GO TO 101
198 IF(IMPLTST.EQ."NO PLOT") GO TO 111
199 IF(XSAMPL.NE."YES") GO TO 111
200 NOVRLY=0
201 IF(IPRE.NE.1) GO TO 1150
202 DO 1149 I=1,2
203 XSAVE(I,1)=YDUR(I)
204 1149 XSAVE(I,251)=2
205 XSAVE(I,251)=2
206 XSAVE(I,252)=0
207 XSAVE(I,253)=0
208 NOVRLY=1
209 1150 CONTINUE
210 NOVRLY=1
211 IF(ISYMBL.EQ."NONE") ISYMBL=-9
212 IF(LINE.EQ."BLANK") LINE=0
213 IF(LINE.EQ."SOLID") LINE=-9
214 IF(KP.GT.3) GO TO 1160
215 DO 1155 I=1,IPOINT
216 XSAVE(KP,I)=XDATA(I)
217 1155 XSAVE(KP,I)=YDATA(I)
218 XSAVE(KP,251)=IPOINT
219 XSAVE(KP,252)=ISYMBL
220 XSAVE(KP,253)=LINE
221 IF(XSAMPL.EQ."YES") GO TO 1162
222 GO TO 111
223 1160 CONTINUE
224 IF(KASG3.EQ.0) CALL ENTRANC(6,"BASC,T 3.

```

PM-5

```

225      KAS63=1
226      WRITE(3,-) IPOINT
227      WRITE(3,-) ISYMBL
228      WRITE(3,-) LINE
229      DO 1165 I=1,IPOINT
230      1165  WRITE(3,-) (DATA(I),YDATA(I))
231      IF(KSAVOV.EQ."YES") GO TO 1362
232      C
233      C STATUS="OVERLAY"
234      C
235      111  CONTINUE
236      C SYMBOL AT EACH POINT
237      READ(2,-,END=1501) ISYMBL
238      IF(ISYMBL.EQ.-9) ISYMBL=4HNONE
239      C LINE TO CONNECT THE POINTS
240      READ(2,-,END=1501) LINE
241      IF(LINE.EQ.0) LINE=5HBLANK
242      IF(LINE.EQ.-5) LINE=5HSLTD
243      C DATA SHOULD FOLLOW
244      READ(2,901,END=1501) INBUF
245      IF(INBUF(1).EQ."DATAFG".AND.INBUF(2).EQ."LLONS.") GO TO 231
246      PRINT 905
247      GO TO 1500
248      231  CONTINUE
249      IPOINT=0
250      CONTINUE
251      READ(2,-,END=1501) XX,YY
252      243  CONTINUE
253      XCHECK=XX+1.
254      YCHECK=YY+1.
255      IF(ABS(XCHECK).LT.1.E-6.AND.ABS(YCHECK).LT.1.E-6) GO TO 232
256      IPOINT=IPOINT+1
257      XDATA(IPOINT)=XX
258      YDATA(IPOINT)=YY
259      GO TO 241
260      232  CONTINUE
261      READ(2,901,END=1501) INBUF
262      IF(INBUF(1).EQ."ENDOFD".AND.INBUF(2).EQ."ATA ") GO TO 251
263      IPOINT=IPOINT+1
264      XDATA(IPOINT)=XX
265      YDATA(IPOINT)=YY
266      BACKSPACE 2
267      READ(2,-) XX,YY
268      GO TO 243
269      251  CONTINUE
270      CALL POSITN(0.,.85)
271      CALL PURGBF
272      CALL HYPERAS(9)
273      CALL FRAME(0.,.2,10.,10.)
274      CALL SHOWDC6H(FILLFR)
275      CALL GRAPHMC(4DATA,5HSCALE1,YDATA,5HSCALE1,IPOINT,ISYMBL,LINE)
276      CALL FRAME(0.,.3,10.,10.)
277      CALL PURGBF
278      READ(2,901,END=1501) INBUF
279      IOSTAT=2
280      IF(INBUF(1).EQ."NEW PL".AND.INBUF(2).EQ."OT ") IOSTAT=1
281      KSAVOV=6H

```


FM-6

```

282      1201 CONTINUE
283      IF(KSAVPL.NE."YES") GO TO 1203
284      IF(IPLTST.EQ."NOPLOT") GO TO 1203
285      CALL WRTXT(0,...7,"SAVE OVERLAYSQUESS SS",...14,0,...0)
286      CALL PURGBF
287      READ(5,501,END=1500) KSAVOV
288      IF(KSAVOV.EQ."NO".OR.KSAVOV.EQ."-2") GO TO 1203
289      IF(KSAVOV.EQ."YES") GO TO 1203
290      IF(KSAVOV.EQ."STOP".OR.KSAVOV.EQ."-1") GO TO 1500
291      CALL POSITN(0,...85)
292      CALL PURGBF
293      CALL WRTxt(3)
294      GO TO 1201
295      1203 CONTINUE
296      IF(KSTOP.EQ.1)CALL WRTXT(0,...5,"READY TO STOPSQESS SS",...14,0,...3)
297      IF(KSTOP.EQ.0.AND.IOSTAT.EQ.1)
298      .CALL WRTXT(0,...5,"READY FOR A NEW PLOTSQUESS SS",...14,0,...0)
299      IF(KSTOP.EQ.0.AND.IOSTAT.EQ.2)
300      .CALL WRTXT(0,...5,"READY FOR ANOTHER OVERLAYSQUESS SS",...14,0,...0)
301      CALL PURGBF
302      READ(5,901,END=1500) KREADY
303      IF(KREADY.EQ."YES".OR.KREADY.EQ."-2") GO TO 1210
304      IF(KREADY.EQ."STOP".OR.KREADY.EQ."-1") GO TO 1500
305      CALL POSITN(0,...45)
306      CALL PURGBF
307      CALL WRTxt(3)
308      GO TO 1203
309      1210 CONTINUE
310      IF(KSAVOV.EQ."YES") GO TO 1361
311      GO TO 1362
312      1361 CONTINUE
313      NOVRLY=NOVRLY+1
314      GO TO 1150
315      1362 CONTINUE
316      KSAVOV=6M
317      IF(KSTOP.EQ.1) GO TO 1301
318      IF(ISTAT.EQ.1) GO TO 1301
319      GO TO 111
320      1301 CONTINUE
321      C
322      C FINISHED WITH THIS SERIES OF OVERLAYS
323      C
324      IF(KSAVPL.NE."YES".AND.KSTOP.EQ.1) GO TO 1500
325      IF(KSAVPL.NE."YES".AND.KSTOP.EQ.0) GO TO 101
326      IPL06=IPL06+1
327      IT=KP
328      IF(IT.GT.5) IT=5
329      CALL CSFSET(SHBLTYP,4HNONE,SHINPAT)
330      IPOINT=XSAVE(1,251)
331      ISYMBL=XSAVE(1,252)
332      IF(ISYMBL.EQ.-9) ISYMBL=4HNONE
333      LINE=XSAVE(1,253)
334      IF(LINE.EQ.0) LINE=5HBLANK
335      IF(LINE.EQ.-9) LINE=5HBLIN
336      DO 1310 I=1,IPOINT
337      XDATA(I)=XSAVE(1,1)
338      YDATA(I)=YSAVE(1,1)
339      1310

```

PM-7

```

339      CALL GRAPH(XDATA,1,YDATA,1,IPOINT,ISYMBL,LINE,INLABL,IYLABL,2,
340      .ITITLE,PGEWID,PGHTE)
341      IF(IT.LT.2) GO TO 1350
342      DO 1330 J=2,IT
343      IPOINT=XSAVE(J,251)
344      DO 1320 I=1,IPOINT
345      XDATA(I)=XSAVE(J,I)
346      YDATA(I)=YSAVE(J,I)
347      ISYMBL=XSAVE(J,252)
348      IF(ISYMBL.EQ.-9) ISYMBL=4HNONE
349      LINE=XSAVE(J,253)
350      IF(LINE.EQ.C) LINE=4HBLANK
351      IF(LINE.EQ.-9) LINE=5HSLID
352      CALL GRAPH(XDATA,5HSCAL1,YDATA,5HSCAL1,IPOINT,ISYMBL,LINE)
353      CONTINUE
354      IF(CKP.LT.6) GO TO 1350
355      REWIND 3
356      DO 1345 J=6,CP
357      READ(3,-) IPOINT
358      READ(3,-) ISYMBL
359      IF(ISYMBL.EQ.-9) ISYMBL=4HNONE
360      READ(3,-) LINE
361      IF(LINE.EQ.0) LINE=5HBLANK
362      IF(LINE.EQ.-9) LINE=5HSLID
363      DO 1340 I=1,IPOINT
364      READ(3,-) XDATA(I),YDATA(I)
365      CALL GRAPH(XDATA,5HSCAL1,YDATA,5HSCAL1,IPOINT,ISYMBL,LINE)
366      CONTINUE
367      REWIND 3
368      CONTINUE
369      CALL GSPSET(5HGRPHCS,120,5HINMBT)
370      IF(MSTOP.EQ.3) GO TO 101
371      GO TO 1500
372      1505 CONTINUE
373      MSTOP=1
374      GO TO 1503
375      1205 CONTINUE
376      MSTOP=1
377      GO TO 1201
378      1501 CONTINUE
379      PRINT 906
380      GO TO 1500
381      899 FORMAT(' NUMBER OF SUCCESSFUL CALLS TO PEPSUB:',I5)
382      900 FORMAT(' NUMBER OF "ESCAPE RETURNS":',I6)
383      901 FORMAT(10A6)
384      902 FORMAT(' NORMAL STOP')
385      903 FORMAT(' **ERROR --- IMPROPER STATUS --- PROGRAM STOPPED')
386      905 FORMAT(' **ERROR --- IMPROPER OPTION FOR DATA --- PROGRAM STOPPED')
387      906 FORMAT(' UNEXPECTED END-OF-FILE')
388      907 FORMAT(' NUMBER OF PLOTS GENERATED:',I5)
389      908 FORMAT(' NO PLOTS GENERATED')
390      909 FORMAT(' ** RUN ID IS:',A6)
391      910 FORMAT(' E N D O F J O B')
392      END

```

106,N I,M,66,6,3.

193602639-LISTER (O). SUBCHR

[illegible]

PM-9

```
54      351  CONTINUE
55          J=(NOUT+5)/6+1
56          IOUT(J)=2MSZ
57      RETURN
58      51   FORPAT(60A1)
59      52   FORMAT(" DUE TO A LARGE NUMBER OF CHARACTERS A LIST WAS TRUNCATED"
60          " )
61      END
186,N,X,N,66,6,3.
```

PM-10

PORT, S LISTER, MYERAS
JRPUR-MACC 4.06 RL1812 07/24-23:33:12

```

393602639* LISTER(0).MYERAS
1      SFOR,I ,PEP-MYERAS
2      SUBROUTINE MYERAS(NOLINE)
3      IT=0
4      CALL BUSET(4HNONE)
5      100  CALL PLNERS
6      IT=IT+1
7      IF(IIT.GE.NOLINE) GO TO 200
8      CALL RI,INFO
9      GO TO 100
10     200  CALL PURGBF
11         CALL BUSET(12Q)
12
13     RETURN
14     END
15     REPR,7 ,PEP-WRTFL
16     X,R,66,8,J.

```

PM-11

BT,5 LISTER.WRTFIL
 IMPUR-WACC 4.00 RLID12 07/24-23:33:13

193602639=LISTER(0).WRTFIL

```

1      SUBROUTINE WRTFIL
2      DIMENSION ISAVE(10,264),INBUF(10)
3      COMMON/TRAN/ISAVE,INBUF,JESCAP,JKEEP
4
5      C
6      C ASSIGN A FILE
7      CALL ERTRAN(0,"CASE,T 2.      .      ")
8      GO TO 501
9      490      CONTINUE
10     JESCAP=JESCAP+1
11     CONTINUE
12     IPOINT=0
13     IF(MSTOP.NE.1) GO TO 503
14     GO TO 599
15     501      CONTINUE
16     C BEGIN READING
17     READ(5,901,END=599) INBUF
18     503      CONTINUE
19     IPOINT=IPOINT+1
20     DO 505 I=1,10
21     ISAVE(I,IPOINT)=INBUF(I)
22     IF(INBUF(1).EQ."NODATA".AND.INBUF(2).EQ."") GO TO 520
23     IF(INBUF(1).EQ."ENDOFFD".AND.INBUF(2).EQ."ATA") GO TO 520
24     GO TO 503
25     520      CONTINUE
26     READ(5,901,END=600) INBUF
27     IF(INBUF(1).EQ."NEW PL".AND.INBUF(2).EQ."OT") GO TO 525
28     IF(INBUF(1).EQ."OVERLA".AND.INBUF(2).EQ."Y") GO TO 525
29     GO TO 503
30     525      CONTINUE
31     IF(ISAVE(1,IPOINT).EQ."NODATA") GO TO 490
32     JKEEP=JKEEP+1
33     DO 530 I=1,IPOINT
34     WRITE(2,901)(ISAVE(J,I),J=1,10)
35     GO TO 495
36     599      CONTINUE
37     IF(IPOINT.NE.0) PRINT 902
38     ENDFILE 2
39     RETURN
40     600      CONTINUE
41     MSTOP=1
42     GO TO 525
43     901      FORMAT(10A6)
44     902      FORMAT(" INPUT FILE IN ERROR")
45     END

```

DE,N I.N,66,6,3.

PM-12

PRT,S LISTER,NAP
JRPUR-WACC 4.06 RL1812 07/24-23:33:14

393602639=LISTER(O),NAP
1 SNAP,I CHEMISTRY*WALTERS//01.BASIC-PEP
2 IN TPFS.PEP-WATN
3 IN TPFS.SUSCHR
4 IN TPFS.PEP-MYERAS
5 IN TPFS.PEP-WATFZL
6 IN TRAN
7 NOT GSPRNT
END,N Y R,44,A,1

Appendix B-4

DASH PATTERNS, PLOT SYMBOLS, AND PAGE FORMATS

Dash Patterns and Dash Mode Plotting (Appendix A)

Argument JDASH in the calling sequences of GRAPH and GRAPHM accepts INTEGER values in the range $1 \leq \text{JDASH} \leq 23$; these values specify that line segments connecting adjacent plotted points be drawn using a dashed line whose pattern is selected by the value of JDASH from the table below. The patterns illustrated are based on a unit length of one inch; changes in the unit length of the page-level coordinate system (effective only when PGWID = 6HPREDEF option is used) increase or decrease the lengths of the dash pattern elements proportionately. (If a unit length less than 0.5 inches is used, the dash element lengths are somewhat greater than expected, since no element may be shorter than 0.05 inches.)

Value of JDASH	Dash Lengths	Dash Pattern
1	0.1	-----
2	0.2	-----
3	0.1 and 0.2, alternating	-----
4	0.3	-----
5	0.1 and 0.3, alternating	-----
6	0.5	-----
7	0.1 and 0.5, alternating	-----
8	0.2 and 0.5, alternating	-----
9	0.75	-----
10	0.1 and 0.75, alternating	-----
11	0.2 and 0.75, alternating	-----
12	0.3 and 0.75, alternating	-----
13	1.0	-----
14	0.1 and 1.0, alternating	-----
15	0.2 and 1.0, alternating	-----
16	0.3 and 1.0, alternating	-----

Value of JDASH	Dash Lengths	Dash Pattern
17	0.5 and 1.0, alternating	— — — — —
18	1.5	— — — — —
19	0.1 and 1.5, alternating	- - — — — -
20	0.2 and 1.5, alternating	- - — — — -
21	0.3 and 1.5, alternating	- - — — — -
22	0.5 and 1.5, alternating	— — — — —
23	0.75 and 1.5, alternating	— — — — —

Centered Symbols (Appendix B)

Value of LSYMBL	Symbol Drawn
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	

Value of LSYMBL	Symbol Drawn
14	
15	

Appendix B-5

SAMPLE RUN WITH EXPLANATION

Pages PD-1 through PD-5 contain an example program using PEPSUB and a sample hard copy plot. Herewith is a line-for-line explanation of what occurred in producing the plot on page PD-5.

Page PD-1:

UWLG is the sign-on code from a DECWRITER, the teletype-like device used for the run. The 1110 computer, recognizing the code, typed back the line starting "MACC...".

An @RUN statement was entered to start interaction (UWLG assigns a phone line but does not allow processing to begin--only a RUN statement can do that). A run identification number, which is necessary to identify any plot which may be produced, is assigned as Y49292. The user's password is solicited and, after being correctly entered in the blacked out space, the run is allowed to continue.

At the time the run was made, there were some problems with the normal version of BASIC, so the back-up version was used. It is anticipated that the normal version will be fixed on or about

August 15, 1977, at which time the line starting "@LIB*BACKUP..." should be replaced by the standard command:

```
@BASIC CHEMISTRY*WALTERS//01.
```

The //01 is the write code for the file CHEMISTRY*WALTERS without which it is impossible to store a new program on the file.

With BASIC running, a program called PLOTDEMO is written, which will produce a parabola. Line 80 is of particular significance. First of all, the first attempt to enter the line was erroneous; the line was ignored by the computer because the command CTRL key with the X key on the DECWRITER was entered (as shown by the two question marks). As the present version of PEPSUB was under development at the time the sample was run, the name of the subroutine was PEP2 rather than PEPSUB. So as of the time this documentation is finished, line 80 should be entered as:

```
80 CALL PEPSUB
```

rather than as

```
80 CALL PEP2
```

as shown here.

The first few lines of the program were then listed. Note that statement 80 was automatically changed to "Gosub 9000". Indeed the first few lines of PEPSUB as given in the listing in Appendix B-2 are present starting at line 9000. Note that the X and Y arrays were dimensioned in statement 10, at the beginning of the program. After this listing was completed, the command to RUN the program was given.

Page PD-2:

The program ran and listed out the data which was stored in the X and Y arrays. Forty-one points were calculated. Notice the effect of round-off error (for example, X for point 15 should have been -0.6 but was instead -0.59999999). This will not show up in the plot but should be considered when writing programs to produce the numbers.

After listing the numbers, PEPSUB was called. The questions were answered so as to have the following effects:

- (A) Hard copy may be obtained.
- (B) Small (11-inch width) paper is to be used.
- (C) Liquid ink will be used (thus allowing for easy tracing or Xerox copying).

Page PD-3:

- (D) As it is desired to plot the data just calculated, the plot type is NEW. If "None" had been entered, no plot would

be generated and question (N) would be asked; "Overlay" would have generated a diagnostic as there are no old plots on which to overlay at this point.

(E) Options are requested by answering YES here. This allows the demonstration of some nonstandard features of PEPSUB.

(F) The title $PARABOLA\ Y=X^{**}2$ was chosen; see page PD-5 to see how this appears on the plot.

(G), (H), (I), (J)

Default (-2) entries were made. This resulted in the title of the X axis being X AXIS, the title of the Y axis being Y AXIS, no symbol at each point, and a solid line connecting the points.

(K) It was decided to make the scales on the axes large enough that the plotted points would all fall within the drawn boundaries without touching those boundaries. X data ran from -2 to +2, so X minima and maxima were set at -2.5 and 2.5 respectively. Had "-2" been entered, the X minima and maxima would have been -2 and +2 respectively, the default values of 0 for minimum and 4 for maximum on the Y axis would have been used. As it was, non-default values were entered. Notice for the Y axis minimum that -1 was the value desired, but a number slightly different from -1 was actually used to prevent PEPSUB from taking an ERROR RETURN.

- (L) The standard plot for small paper is 10.8 by 10.8 inches. It was decided that standard paper size of 8.5 by 11 inches would be desirable for the output plot so that it would fit onto standard size paper. The answers to question (L), (L-2), and (L-3) allowed 0.1 inch margin on each side of the plot area and fit the whole plot into the proper space. Note that the dimensions are for the plots including labels; the actual drawing exclusive of labels is three inches smaller in each direction than the numbers specified in the (L) questions.
- (M) Data to be plotted appears in the X and Y arrays. The alternative would be to type in the numbers from the terminal which could be done if the answer "PEP" were given. Question (M-2) gives the number of points to be plotted. All 41 calculated points are to be plotted. If a number greater than 41 had been entered, a line would have been drawn from the last plotted point (2,4) to the origin (0,0) and the point (0,0) repeatedly plotted.
- (N) As there are more features of PEPSUB to be demonstrated, the answer to question (N) was NO. A normal return ensued.

At this point the main program inquires as to whether another call to PEPSUB is desired. The answer is affirmative. Note that until question (N) is answered "YES", termination of the program will result in loss of plotted output, i.e. no plots will be obtainable. The rest of page PD-3 shows the closing of the plot file, a decision not to view the plot immediately, and another question as to what should happen next by the main program.

Page PD-4:

Now that the file has been closed, notice what happens when PEPSUB is called. After exiting from PEPSUB, the main program is shut down. BYE nad @FIN complete the run.

To obtain the plot shown on page PD-5, it was necessary to run out the plot on the PEP terminal. The commands used were as follows:

```
UWGT  
@RUN AS,41000,1893602639,$5.00
```

(a run ID number was assigned by the 1110 and a password entered)

```
@ADD,P PLOT.
```

(Do not forget that period! Also, only the individual who made a PEPSUB run can obtain plot using the above command. Second parties can obtain the plot if they know the original user's ID number. For example, the ID number shown in all

the sample runs is 1893602639. If user 12345 wanted to obtain plot from 1893602639's runs, he would enter, instead of the @ADD command above,

@ADD,P 1893602639*PLOT.)

BASIC-PEP was automatically called into action by the @ADD command. To all further questions posed by the program, the answer YES was given. The run ID was noted at the end of the run just before @FIN,C was entered, and the plot obtained from the I/O window in the basement of the computer center. A photocopy of that plot appears on page PD-5.

Total cost of the two runs was \$1.13. There are some hidden costs, however:

- (1) File charges amounted to about 40¢. This is unavoidable but is fairly independent of the number of plots produced by any given run.
- (2) Plotting itself took three minutes, which costs \$1.00 using liquid ink.
- (3) Evening rates applied, so that \$1.13 is only 60% of the full daytime charge. Overall, had this run been made during the day the cost including hidden costs would have been \$3.28. Experience shows that marginal cost for plots other than the first in a run is about \$1.00 including all hidden charges.

FD-1

UMLG
 MACC 33.14 TTY U02044
 BRUN AS+41000+1893602639+15.00
 RUNID:Y49292 DATE:073077 TIME:095519
 PASSWORD PLEASE

 CONTINUE
 @LIB*BACKUP.BASIC CHEMISTRY*WALTERS.

BASIC X4.0.4 09:55:37 30 JUL 77

```
>NEW:PLOTDEMO
>10 DIM X(250),Y(250)
>20 PRINT "N","X","Y"
>30 FOR N=1 TO 41
>40 LET X(N)=(N-21)/10
>50 LET Y(N)=X(N)*2
>60 PRINT N,X(N),Y(N)
>70 NEXT N
>80 ???
>90 CALL PEP2
>90 PRINT "AGAIN"
>100 INPUT E$
>110 IF E$="YES" THEN 90
>120 STOP
>99999 END
>LIST 1,9010
```

PLOTDEMO 09:59:13 30 JUL 77

```
10 DIM X(250),Y(250)
20 PRINT "N","X","Y"
30 FOR N=1 TO 41
40 LET X(N)=(N-21)/10
50 LET Y(N)=X(N)*2
60 PRINT N,X(N),Y(N)
70 NEXT N
80 GOSUB 9000
90 PRINT "AGAIN"
100 INPUT E$
110 IF E$="YES" THEN 80
120 STOP
9000 " "
9002 "ENTER PEP SUBROUTINE"
9004 " "
9006 DATA HALF,HALF,THFULL,BHFULL,THFULL,BHFULL,FULL,FULL,THFULL
9008 DATA THFULL,FULL,FULL,FULL,FULL,DOUBLE,DOUBLE,DOUBLE,LHDBLE
9010 DATA RHDBLE,LHDBLE,RHDBLE,RHDBLE,RHDBLE,LHDBLE,LHDBLE,DOUBLE
```

>RUN

FD-2

PLOTDEMO 09:59:45 30 JUL 77

N	X	Y
1	-2	4
2	-1.9	3.61
3	-1.8	3.24
4	-1.7	2.89
5	-1.6	2.56
6	-1.5	2.25
7	-1.4	1.96
8	-1.3	1.69
9	-1.2	1.44
10	-1.1	1.21
11	-1	1
12	-.9	.80999999
13	-.8	.63999999
14	-.7	.48999999
15	-.59999999	.35999999
16	-.5	.25
17	-.4	.16
18	-.3	.09
19	-.2	.04
20	-.1	.01
21	0	0
22	.1	.01
23	.2	.04
24	.3	.09
25	.4	.16
26	.5	.25
27	.59999999	.35999999
28	.7	.48999999
29	.8	.63999999
30	.9	.80999999
31	1	1
32	1.1	1.21
33	1.2	1.44
34	1.3	1.69
35	1.4	1.96
36	1.5	2.25
37	1.6	2.56
38	1.7	2.89
39	1.8	3.24
40	1.9	3.61
41	2	4

ENTER PEP SUBROUTINE

A) SHOULD CALCOMP PLOTTER CAPABILITY BE TURNED ON? YES

B) PAPER SIZE ('LARGE' OR 'SMALL')? SMALL

C) LIQUID INK ('YES' OR 'NO')? YES

PD-3

D) TYPE OF PLOT: NEW, OVERLAY, OR NONE? NEW

E) OPTIONS? YES

F) TITLE? PARABOLA $Y=X^2+2$

G) X AXIS LABEL? -2

H) Y AXIS LABEL? -2

I) SYMBOL CODE? -2

J) DASH CODE? -2

K-1) MAXIMUM (X AXIS)? 2.5

K-2) MINIMUM (X AXIS)? -2.5

K-3) MAXIMUM (Y AXIS)? 5

K-4) MINIMUM (Y AXIS)? -1.0001

L) SPECIAL PAGE CODE? NUMBER

L-2) SIZE OF X AXIS? 8.3

L-3) SIZE OF Y AXIS? 10.8

M) DATA FROM PEP OR X & Y ARRAYS
ANSWER ('PEP' OR 'XY')? XY

N-2) HOW MANY POINTS? 41

N) DONE WITH PLOTTING FOR THIS RUN? NO

NORMAL RETURN

AGAIN? YES

ENTER PEP SUBROUTINE

D) TYPE OF PLOT: NEW, OVERLAY, OR NONE? NONE

N) DONE WITH PLOTTING FOR THIS RUN? YES

** FILE HAS BEEN CLOSED. NO MORE PLOTS ALLOWED IN THIS RUN.

O) TO PLOT ON THE PEP TERMINAL IMMEDIATELY, TYPE 'PEP'
OTHERWISE TYPE 'TTY' OR 'BATCH'? TTYNO EXIT FROM BASIC
FURTHER CALLS TO PEPSUB WILL NOT PERMIT PLOTTING.
AGAIN? YES

FD-4

ENTER PEP SUBROUTINE

** FILE WAS CLOSED ON THE LAST CALL.
NO MORE PLOTS ALLOWED.

Q) TO PLOT ON THE PEP TERMINAL IMMEDIATELY, TYPE 'PEP'
OTHERWISE TYPE 'TTY' OR 'BATCH'? TTY

NO EXIT FROM BASIC
FURTHER CALLS TO PEP SUB WILL NOT PERMIT PLOTTING.
AGAIN? NO

TIME : 1.100

>BYE

UNIVAC BASIC 10:04:10 30 JUL 77
@FIN,C

RUNID: Y49292 PROJECT: 41000

USER: 1893402639

ITEM	AMOUNT	COST
CPU TIME	0:00:03.052	\$0.17
FILE I/O REQUEST	47	\$0.04
FILE I/O WORDS	44415	\$0.04
SNAP REQUESTS	1	\$0.00
SNAP WORDS	19456	\$0.01
MEMORY USAGE	0.131	\$0.14
CARDS IN	540	\$0.08
PAGES PRINTED	3	\$0.04
CONNECT MINUTES	8	\$0.08
ER + CC	8	\$0.09
JOB CHARGE	1	\$0.04
TOTAL COST		\$0.75

BASED ON RATES FOR EVENING RUNS
USER BALANCE \$300.00

INITIATION TIME: 09:55:19 JUL 30,1977

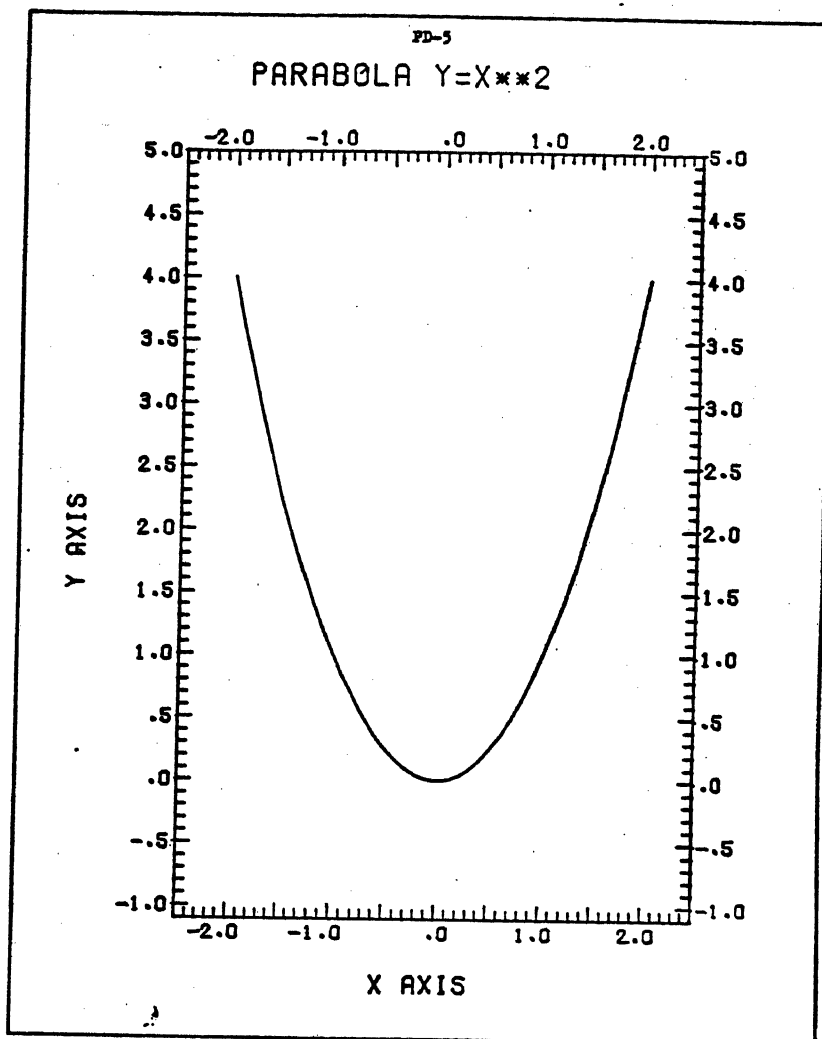
TERMINATION TIME: 10:04:15 JUL 30,1977

PREVIOUS RUN TIME: 09:54:46 JUL 30,1977

TERMINAL INACTIVE

>

Note: Separate run at the PEP terminal to produce plot cost \$0.48 at evening rates.



Appendix C

DERIVATION OF SOURCE CAPACITOR CHARGING EQUATIONS

In this appendix, a detailed derivation is given for the equations describing source capacitor charging behavior. This is done in three stages:

- (1) circuit description and derivation of differential equations describing the circuit;
- (2) solution of the differential equations;
- (3) application of the solution to the initial conditions present in the source.

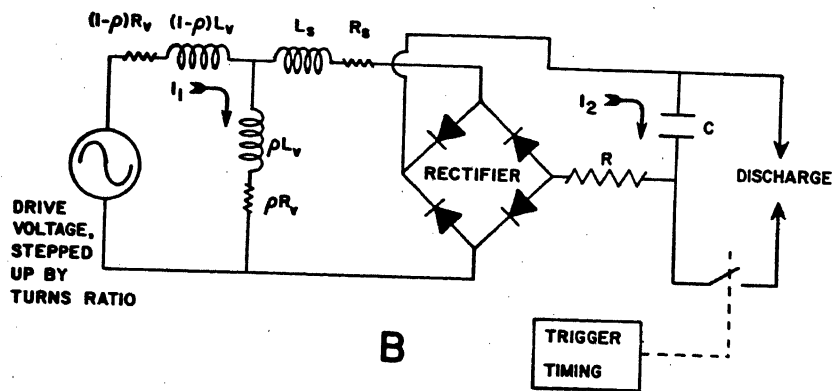
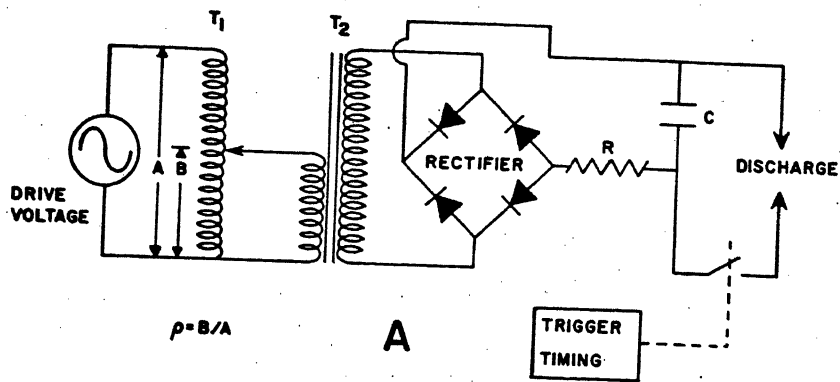
I. Circuit Description

Figure C-1-A shows the circuitry for a spark source in which the control and discharge circuit elements are shown only in general terms, whereas the charging elements are shown explicitly. This source allows for variable peak capacitor voltages by use of a Variac (autotransformer T_1). Computationally it is inconvenient to view the circuit with the Variac operating on one side of the step up transformer (T_2) and the remaining circuit components on

Figure C-1

Source Equivalent Circuits

- (A) full charging circuit
- (B) charging circuit restated for simplified
computation of charging current and voltage.



the other side of this transformer. An equivalent circuit which circumvents this inconvenience is shown in Figure C-1-B.

The Variac is an inductive voltage divider with division ratio ρ ; the total inductance of the Variac as reflected through the step-up transformer is L_V and its total winding resistance is R_V . The step-up transformer has reflected stray inductance L_S and reflected winding resistance R_S . A full wave rectifier, charging resistor R , and storage capacitor C complete the charging circuit. Also of effect on the charging circuit is the discharge path which will be viewed as either an open circuit or an ideal capacitor short circuit depending on whether a discharge is actually occurring.

The drive voltage in Figure C-1, parts A and B is sinusoidal. In part A, line AC voltage is stepped down through the Variac, then up through transformer T_2 ; in part B the drive voltage is equal to line voltage times the turns ratio of transformer T_2 , and is subsequently stepped down through the Variac equivalent resistance/inductance network to obtain the desired voltage impinging on the rectifier bridge. Current I_1 flows in the loop [line drive, $(1-\rho)R_V$, $(1-\rho)L_V$, ρL_V , ρR_V , line drive] and current I_2 flows in loop [line drive, $(1-\rho)R_V$, $(1-\rho)L_V$, L_S , R_S , rectifier, C , R , rectifier, line drive].

The following impedance relationships will be applied:

$$V_R = IR \quad (C-1)$$

$$V_C = \frac{1}{C} \int I \, dt \quad (C-2)$$

$$V_L = L \frac{dI}{dt} \quad (C-3)$$

and the drive voltage in circuit B will be given as

$$V_T = V_T^P \cos(\theta - \theta_0) \quad (C-4)$$

where

V_T^P is the peak voltage produced by the line/transformer combination.

$$\theta = 2\pi ft$$

f = line frequency

t = time since system was turned on and capacitor charging started.

$$\theta_0 = 2\pi ft_0$$

t_0 = time of charging initiation referenced to peak line voltage.

(The choice of cosine voltage dependence is arbitrary--sine voltage dependence gives results identical except for phase factors, which are shifted 90°.)

The differential equation governing the far left loop of the circuit is:

$$\begin{aligned} V_T^P \cos(\theta - \theta_0) = & (1-\rho)R_V(I_1 + I_2) + (1-\rho)L_V \frac{d(I_1 + I_2)}{dt} \\ & + \rho L_V \frac{dI_1}{dt} + \rho R_V I_1. \end{aligned} \quad (C-5)$$

In the central circuit loop, diode impedances are lumped with resistor R's resistance and capacitor C's capacitance. Thus internal diode behavior need not be explicitly accounted for at this stage. The central loop's differential equation is:

$$\begin{aligned} V_T^P \cos(\theta - \theta_0) = & (1-\rho)R_V(I_1 + I_2) + (1-\rho)L_V \frac{d(I_1 + I_2)}{dt} \\ & + L_S \frac{dI_2}{dt} + R_S I_2 + \frac{1}{C} \int I_2 dt + R I_2. \end{aligned} \quad (C-6)$$

The quantities of interest are the capacitor voltage, V_C , and I_2 , the current charging the capacitor and thus controlling V_C .

I_1 may be eliminated from Equations (C-5) and (C-6) by substituting Eq. (C-5) into Eq. (C-6) after suitably rearranging Eq. (C-5). The arrangements of Eq. (C-5) are:

$$V_T^P \cos(\theta - \theta_0) = R_V I_1 + L_V \frac{dI_1}{dt} + (1-\rho)R_V I_2 + (1-\rho)L_V \frac{dI_2}{dt} \quad (C-7a)$$

$$R_V I_1 + L_V \frac{dI_1}{dt} = V_\tau^P \cos(\theta - \theta_0) - (1-\rho)R_V I_2 - (1-\rho)L_V \frac{dI_2}{dt} \quad (C-7b)$$

$$(1-\rho)R_V(I_1+I_2) + (1-\rho)L_V \frac{d(I_1+I_2)}{dt} = V_\tau^P \cos(\theta - \theta_0) - \rho(L_V \frac{dI_1}{dt} + R_V I_1) \quad (C-7c)$$

Inserting (C-7b) into the right side of (C-7c) and thence (C-7c) into (C-6) gives

$$\begin{aligned} V_\tau^P \cos(\theta - \theta_0) &= V_\tau^P \cos(\theta - \theta_0) - \rho(V_\tau^P \cos(\theta - \theta_0) - (1-\rho)R_V I_2 \\ &\quad - (1-\rho)L_V \frac{dI_2}{dt}) + L_S \frac{dI_2}{dt} + R_S I_2 + R I_2 + \frac{1}{C} \int I_2 dt \end{aligned} \quad (C-8)$$

This in turn may be arranged by grouping terms to give

$$\begin{aligned} \rho V_\tau^P \cos(\theta - \theta_0) &= (\rho(1-\rho)R_V + R + R_S)I_2 + \frac{1}{C} \int I_2 dt \\ &\quad + (\rho(1-\rho)L_V + L_S) \frac{dI_2}{dt} \end{aligned} \quad (C-9)$$

This simplification was possible due to the choice of loops for I_1 and I_2 ; the neat decoupling of I_1 is difficult if I_1 and I_2 are defined in such a way as to flow through ρR_V and ρL_V in opposition, as would be legitimate in setting up the problem.

Define the following:

$$\rho V_{\tau}^P = V_p \quad (C-10)$$

$$V_t = V_p \cos(\theta - \theta_0) \quad (C-11)$$

$$\rho(1-\rho)R_V + R + R_S = R_{tot} \quad (C-12)$$

$$\rho(1-\rho)L_V + L_S = L. \quad (C-13)$$

Substituting the above into Equation (C-9), the charging equation becomes

$$V_p \cos(\theta - \theta_0) = R_{tot} I_2 + \frac{1}{C} \int I_2 dt + L \frac{dI_2}{dt}. \quad (C-14)$$

This is the same equation which governs an unbranched R-L-C series circuit with sinusoidal drive of arbitrary phase and initial conditions. Solution of a linear circuit is simpler than solution of a branched circuit, and a closed form descriptive equation will now be derived.

II. Solution of Equations for Charging Voltage and Current

The solution of Equation (C-14) is carried out here in a manner similar to Steinmetz's derivations in 1909, as reprinted

in Lectures on Electrical Engineering, Volume 2, by C. P. Steinmetz, edited by P. L. Alger (Dover Publications, New York, 1971). The major difference is in the handling of "damping conditions," that is, the relative size of circuit resistance compared to capacitive or inductive impedance. Steinmetz derived separate equations for circuit behavior in overdamped, underdamped, and critically damped conditions. Here two functions of complex variables ($\cosh$ and $\sinh$) are defined which permit unified treatment without explicit concern for damping conditions. This aids in writing calculational software and highlights charging characteristics based on the existence of components, rather than their relative values.

Equation (C-14) may be solved for V_C , using Equation (C-2), so that

$$V_C = V_p \cos(\theta - \theta_0) - R_{\text{tot}} I_2 - L \frac{dI_2}{dt}. \quad (\text{C-15})$$

Or, changing all t 's to θ 's using the definition of θ from the discussion after Equation (C-3),

$$V_C = V_p \cos(\theta - \theta_0) - R_{\text{tot}} I_2 - \omega L \frac{dI_2}{d\theta} \quad (\text{C-16})$$

where $\omega = 2\pi f$. Note one may also write

$$\frac{1}{C} \int I_2 dt = \frac{1}{\omega C} \int I_2 d\theta. \quad (\text{C-17})$$

Equation (C-14) is an integral equation in I_2 ; a simpler form to solve is a second order differential equation in I_2 , which may be obtained by differentiating Equation (C-14) with respect to θ :

$$-V_p \sin(\theta - \theta_0) = R_{\text{tot}} \frac{dI_2}{d\theta} + \frac{I_2}{\omega C} + \omega L \frac{d^2 I_2}{d\theta^2} \quad (\text{C-18})$$

Notation may be simplified still farther by defining

$$x_L = \omega L \quad (\text{C-19})$$

$$x_C = \frac{1}{\omega C} \quad (\text{C-20})$$

so that the quantities of interest become

$$V_C = V_p \cos(\theta - \theta_0) - R_{\text{tot}} I_2 - x_L \frac{dI_2}{d\theta} \quad (\text{C-21})$$

$$x_L \frac{d^2 I_2}{d\theta^2} + R_{\text{tot}} \frac{dI_2}{d\theta} + x_C I_2 + V_p \sin(\theta - \theta_0) = 0 \quad (\text{C-22})$$

If any solution is obtained to a second order linear differential equation, then the solution is unique. Previous solution of differential equations or laboratory observation of R-L-C circuits indicates the solution to this problem is a linear combination of a transient, exponentially decaying, term and an oscillatory, sinusoidal term (this result could also be obtained

using Laplace Transformation, but the algebra at times becomes involved). Thus a formal solution may be written for I_2 :

$$I_2 = Ae^{a\theta} + B\cos(\theta-\sigma) \quad (C-23)$$

where A , a , B , and σ are constants to be determined from the initial and boundary conditions.

Several of the constants may be evaluated without further recourse to physics. Inserting Equation (C-23) into Equation (C-22) and carrying out the indicated differentiations gives:

$$\begin{aligned} x_L(Aa^2e^{a\theta} - B\cos(\theta-\sigma)) + R_{tot}(Aae^{a\theta} - B\sin(\theta-\sigma)) \\ + x_C(Ae^{a\theta} + B\cos(\theta-\sigma)) + V_p \sin(\theta-\theta_0) = 0. \end{aligned} \quad (C-24)$$

The exponential terms and sinusoidal terms are linearly independent, yet Equation (C-24) must be satisfied for all values of θ . Thus the sum of the exponential terms and the sum of the sinusoidal terms must each independently sum to zero. Dealing first with the exponential terms:

$$(Aa^2x_L + AaR_{tot} + x_CA)e^{a\theta} = 0 \quad (C-25)$$

$$a^2x_L + R_{tot}a + x_C = 0. \quad (C-26)$$

Solving for "a" using the "quadratic formula,"

$$a = \frac{-R_{\text{tot}} \pm \sqrt{R_{\text{tot}}^2 - 4x_L x_C}}{2x_L} \quad (\text{C-27})$$

"a" may assume two distinct values, yet appears in a term given as

$$Ae^{a\theta}$$

To circumvent this seeming contradiction, the exponential term is split into two terms, one for the value of a derived from the plus sign in Equation (C-27), and one from the minus sign derived value:

$$Ae^{a\theta} = A_1 e^{a_1\theta} + A_2 e^{a_2\theta} \quad (\text{C-28})$$

$$a_1 = \frac{-R_{\text{tot}} + \sqrt{R_{\text{tot}}^2 - 4x_L x_C}}{2x_L} \quad (\text{C-29})$$

$$a_2 = \frac{-R_{\text{tot}} - \sqrt{R_{\text{tot}}^2 - 4x_L x_C}}{2x_L} \quad (\text{C-30})$$

For convenience, define

$$s^2 = R^2 - 4x_L x_C \quad (\text{C-31})$$

Complications arising if $R_{\text{tot}}^2 < 4x_L x_C$ will be dealt with later. Meanwhile, a_1 and a_2 will be written in terms of $\sqrt{s}$ rather than in terms of s .

Turning to the sinusoidal terms,

$$\begin{aligned} -Bx_L \cos(\theta - \sigma) - R_{\text{tot}} B \sin(\theta - \sigma) + x_C B \cos(\theta - \sigma) \\ + V_p \sin(\theta - \theta_0) = 0. \end{aligned} \quad (\text{C-32})$$

To facilitate solution, the sin and cos terms will be expanded to eliminate sums of angles in their arguments. Recall

$$\cos(\delta - \eta) = \cos \delta \cos \eta + \sin \delta \sin \eta \quad (\text{C-33})$$

$$\sin(\delta - \eta) = \sin \delta \cos \eta - \cos \delta \sin \eta. \quad (\text{C-34})$$

Using Equations (C-33) and (C-34) with Equation (C-32) and then grouping coefficients of $\sin \theta$ and $\cos \theta$, Equation (C-35) is obtained:

$$\begin{aligned} (-Bx_L \cos \sigma + R_{\text{tot}} B \sin \sigma + x_C B \cos \sigma - V_p \sin \theta_0) \cos \theta \\ + (-Bx_L \sin \sigma - R_{\text{tot}} B \cos \sigma + x_C B \sin \sigma + V_p \cos \theta_0) \sin \theta = 0. \end{aligned} \quad (\text{C-35})$$

Again, Equation (C-35) must be true for all values of θ , so the coefficients of the sin and cos terms must independently equal zero. Thus,

$$B(x_C - x_L)\cos\sigma + R_{\text{tot}}B\sin\sigma - V_p\sin\theta_0 = 0 \quad (\text{C-36})$$

$$B(x_C - x_L)\sin\sigma - R_{\text{tot}}B\cos\sigma + V_p\cos\theta_0 = 0 \quad (\text{C-37})$$

Equations (C-36) and (C-37) are two equations in two unknowns and may be solved directly. In fact the two equations are redundant and either may be used to evaluate B and σ . Rearranging (C-36):

$$R_{\text{tot}}\sin\sigma - (x_L - x_C)\cos\sigma = \frac{V_p}{B}\sin\theta_0 \quad (\text{C-38})$$

The left side of (C-37) may be changed to a form similar to that of (C-34) by defining two quantities:

$$z_0 \equiv \sqrt{R_{\text{tot}}^2 + (x_L - x_C)^2} \quad (\text{C-39})$$

$$\gamma = \arctan\left(\frac{x_L - x_C}{R_{\text{tot}}}\right) \quad (\text{C-40})$$

Equations (C-39) and (C-40) did not just "appear." The difference between (C-34) and (C-38) is that the left side of (C-38) contained R_{tot} where (C-34) had a cosine term, and $(x_L - x_C)$ where (C-34) had a sine term. As the right side of (C-38) has $\sin\theta_0$, it would be convenient if the left side of the equation could be combined to give $\sin(\phi)$, where ϕ is some angle which can then be related to θ_0 . If $x_L - x_C$ is in the role of a sine term, and R_{tot} is in the role of a cosine term, then

$$\tan \gamma = \frac{\sin \gamma}{\cos \gamma} = \frac{x_L - x_C}{R_{\text{tot}}} \quad (\text{C-41})$$

Both sine and cosine have a range $[-1, 1]$, and so a normalization factor is needed. Since

$$\sin^2 \gamma + \cos^2 \gamma = 1 \quad (\text{C-42})$$

for all γ , it followed that for a normalization factor z_0 ,

$$\sin \gamma = \frac{x_L - x_C}{z_0}, \quad \cos \gamma = \frac{R_{\text{tot}}}{z_0} \quad (\text{C-43})$$

Equations (C-41) and (C-42) would hold by definition. Inserting (C-43) into (C-42) gives the value of z_0 shown in (C-40). Equation (C-38) is divided by z_0 , (C-43) is applied, and

$$\sin \sigma \cos \gamma - \cos \sigma \sin \gamma = \sin(\sigma - \gamma) = \frac{V_D}{Bz_0} \sin \theta_0 \quad (\text{C-44})$$

As (C-44) must hold for all V_D , z_0 , and θ_0 ,

$$\frac{V_D}{Bz_0} \equiv 1, \quad B = \frac{V_D}{z_0} \quad (\text{C-45})$$

and

$$\sigma - \gamma = \theta_0, \quad \sigma = \theta_0 + \gamma \quad (\text{C-46})$$

B and γ are now established in terms of circuit parameters.

Now all constants except A_1 and A_2 have been evaluated;
to recapitulate:

$$I_2 = A_1 \exp\left[\frac{-R_{\text{tot}} + \sqrt{s^2}}{2x_L} \theta\right] + A_2 \exp\left[\frac{-R_{\text{tot}} - \sqrt{s^2}}{2x_L} \theta\right] + \frac{V_D}{Z_0} \cos(\theta - (\theta_0 + \gamma)) . \quad (\text{C-47})$$

Now initial conditions must be supplied. At $\theta = 0$,

$$I_2 = I_0 \quad (\text{C-48})$$

$$V_C = V_0 . \quad (\text{C-49})$$

Combining Equations (C-47) and (C-48) and recalling $e^0 = 1$ and $\cos(-\phi) = \cos\phi$

$$I_0 = A_1 + A_2 + \frac{V_D}{Z_0} \cos(\theta_0 + \gamma) . \quad (\text{C-50})$$

Before A_1 and A_2 can be evaluated, the formulas for I_2 must be substituted into Equation (C-21) to relate V_C and V_0 to I_2 and I_0 .

The steps involved are:

$$\begin{aligned}
 V_C = & V_p \cos(\theta - \theta_0) - R_{tot} \left(A_1 \exp\left[\frac{-R_{tot} + \sqrt{s^2}}{2x_L} \theta\right] + A_2 \exp\left[\frac{-R_{tot} - \sqrt{s^2}}{2x_L} \theta\right] \right) \\
 & + \frac{V_p}{z_0} \cos(\theta - (\theta_0 + \gamma)) - x_L \left(A_1 \left(\frac{-R_{tot} + \sqrt{s^2}}{2x_L} \exp\left[\frac{-R_{tot} + \sqrt{s^2}}{2x_L} \theta\right] \right) \right. \\
 & \left. + A_2 \left(\frac{-R_{tot} - \sqrt{s^2}}{2x_L} \exp\left[\frac{-R_{tot} - \sqrt{s^2}}{2x_L} \theta\right] \right) - \frac{V_p}{z_0} \sin(\theta - (\theta_0 + \gamma)) \right) .
 \end{aligned}
 \tag{C-51}$$

Set $\theta = 0$.

$$\begin{aligned}
 V_0 = & V_p \cos \theta_0 - R_{tot} \left(A_1 + A_2 + \frac{V_p}{z_0} \cos(\theta_0 + \gamma) \right) \\
 & - x_L \left(A_1 \left(\frac{-R_{tot} + \sqrt{s^2}}{2x_L} \right) + A_2 \left(\frac{-R_{tot} - \sqrt{s^2}}{2x_L} \right) + \frac{V_p}{z_0} \sin(\theta_0 + \gamma) \right)
 \end{aligned}
 \tag{C-52}$$

$$\begin{aligned}
 V_0 = & V_p \left(\cos \theta_0 - \frac{R_{tot}}{z_0} \cos(\theta_0 + \gamma) - \frac{x_L}{z_0} \sin(\theta_0 + \gamma) \right) \\
 & - A_1 \left(\frac{R_{tot} + \sqrt{s^2}}{2} \right) - A_2 \left(\frac{R_{tot} - \sqrt{s^2}}{2} \right)
 \end{aligned}
 \tag{C-53}$$

$$\begin{aligned}
 V_0 = & V_p \left(\cos \theta_0 - \cos \gamma \cos(\theta_0 + \gamma) - \frac{(x_L - x_C)}{z_0} \sin(\theta_0 + \gamma) - \frac{x_C}{z_0} \sin(\theta_0 + \gamma) \right) \\
 & - A_1 \left(\frac{R_{tot} + \sqrt{s^2}}{2} \right) - A_2 \left(\frac{R_{tot} - \sqrt{s^2}}{2} \right)
 \end{aligned}
 \tag{C-54}$$

$$\begin{aligned}
 V_0 &= V_p (\cos \theta_0 - \cos \gamma \cos(\theta_0 + \gamma) - \sin \gamma \sin(\theta_0 + \gamma) - \frac{x_C}{z_0} \sin(\theta_0 + \gamma)) \\
 &\quad - A_1 \left(\frac{R_{\text{tot}} + \sqrt{s^2}}{2} \right) - A_2 \left(\frac{R_{\text{tot}} - \sqrt{s^2}}{2} \right) \quad (C-55)
 \end{aligned}$$

$$\begin{aligned}
 V_0 &= V_p (\cos \theta_0 - \cos(\theta_0 + \gamma - \gamma) - \frac{x_C}{z_0} \sin(\theta_0 + \gamma)) \\
 &\quad - A_1 \left(\frac{R_{\text{tot}} + \sqrt{s^2}}{2} \right) - A_2 \left(\frac{R_{\text{tot}} - \sqrt{s^2}}{2} \right) \quad (C-56)
 \end{aligned}$$

$$V_0 = -\frac{V_p x_C}{z_0} \sin(\theta_0 + \gamma) - A_1 \left(\frac{R_{\text{tot}} + \sqrt{s^2}}{2} \right) - A_2 \left(\frac{R_{\text{tot}} - \sqrt{s^2}}{2} \right) \quad (C-57)$$

Equations (C-50) and (C-57) are two equations in the two unknowns, A_1 and A_2 . Solving these by substitution:

$$A_1 = I_0 - A_2 - \frac{V_p}{z_0} \cos(\theta_0 + \gamma) \quad (C-58)$$

$$\begin{aligned}
 V_0 &= -\frac{V_p x_C}{z_0} \sin(\theta_0 + \gamma) - \left(I_0 - A_2 - \frac{V_p}{z_0} \cos(\theta_0 + \gamma) \right) \left(\frac{R_{\text{tot}} + \sqrt{s^2}}{2} \right) \\
 &\quad - A_2 \left(\frac{R_{\text{tot}} - \sqrt{s^2}}{2} \right) \quad (C-59)
 \end{aligned}$$

$$\begin{aligned}
 V_0 &= \frac{-V_p x_C}{z_0} \sin(\theta_0 + \gamma) - \frac{I_0 R_{\text{tot}}}{2} + \frac{A_2 R_{\text{tot}}}{2} + \frac{V_p R_{\text{tot}}}{2z_0} \cos(\theta_0 + \gamma) \\
 &\quad - \frac{I_0 \sqrt{s^2}}{2} + \frac{A_2 \sqrt{s^2}}{2} + \frac{V_p \sqrt{s^2}}{2z_0} \cos(\theta_0 + \gamma) - \frac{A_2 R_{\text{tot}}}{2} + \frac{A_2 \sqrt{s^2}}{2} \quad (C-60)
 \end{aligned}$$

$$V_0 + \frac{V_p x_C}{z_0} \sin(\theta_0 + \gamma) + \frac{I_0 R_{tot}}{2} - \frac{V_p R_{tot}}{2z_0} \cos(\theta_0 + \gamma) + \frac{I_0 \sqrt{s^2}}{2} - \frac{V_p \sqrt{s^2}}{2z_0} \cos(\theta_0 + \gamma) = A_2 \sqrt{s^2} \quad (C-61)$$

$$A_2 = \frac{V_p}{\sqrt{s^2} z_0} (x_C \sin(\theta_0 + \gamma) - \frac{R_{tot}}{2} \cos(\theta_0 + \gamma) - \frac{\sqrt{s^2}}{2} \cos(\theta_0 + \gamma)) + \frac{V_0 + \frac{I_0}{2} (R_{tot} + \sqrt{s^2})}{\sqrt{s^2}} \quad (C-62)$$

$$A_2 = - \frac{V_p}{\sqrt{s^2} z_0} \left(\frac{R_{tot} + \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) + \frac{V_0 + \frac{I_0}{2} (R_{tot} + \sqrt{s^2})}{\sqrt{s^2}} \quad (C-63)$$

Inserting (C-63) into (C-58),

$$A_1 = I_0 - \frac{V_p}{z_0} \cos(\theta_0 + \gamma) + \frac{V_p}{z_0 \sqrt{s^2}} \left(\frac{R_{tot} + \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) - \frac{V_0 + \frac{I_0}{2} (R_{tot} + \sqrt{s^2})}{\sqrt{s^2}} \quad (C-64)$$

$$A_1 = \frac{I_0}{2} \left(1 - \frac{R_{tot}}{\sqrt{s^2}} \right) + \frac{V_p}{z_0 \sqrt{s^2}} \left(\frac{R_{tot} - \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) - \frac{V_0}{\sqrt{s^2}} \quad (C-65)$$

$$A_1 = \frac{V_p}{z_0 \sqrt{s^2}} \left(\frac{R_{tot} - \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) - \frac{V_0 + \left(\frac{R_{tot} - \sqrt{s^2}}{2} \right) I_0}{\sqrt{s^2}} \quad (C-66)$$

Regardless of circuit parameters R , L , C , t_0 , V_p , I_0 , V_0 , or finite positive f , (A_1 and A_2 inserted in (C-58)):

$$I_2 = \frac{V_p}{z_0} \cos(\theta - (\theta_0 + \gamma)) + \left(\frac{V_p}{z_0 \sqrt{s^2}} \left(\frac{R_{tot} - \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) - \frac{V_0 + \left(\frac{R_{tot} - \sqrt{s^2}}{2} \right) I_0}{\sqrt{s^2}} \right) \times \exp\left[\frac{-R_{tot} + \sqrt{s^2}}{2x_L} \theta \right] - \left(\frac{V_p}{z_0 \sqrt{s^2}} \left(\frac{R_{tot} + \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) - \frac{V_0 + \frac{I_0}{2}(R_{tot} + \sqrt{s^2})}{\sqrt{s^2}} \right) \exp\left[\frac{-R_{tot} - \sqrt{s^2}}{2x_L} \theta \right] \quad (C-67)$$

At this point, many approaches to the solution of differential equations would concentrate on the fact that $\sqrt{s^2}$ may be purely

imaginary ($R^2 - 4x_L x_C$ may be negative), and embark on separate expressions originating from Eq. (C-67) for s^2 positive, negative, or zero. The present approach instead will rearrange Eq. (C-67) until all occurrences of $\sqrt{s^2}$ are appropriately grouped, and then two functions of $\sqrt{s^2}$ will be defined which will succinctly account for all values of s^2 and allow a single form of the solution to the problem without regard to circuit parameter values.

To arrange the equations so that the functions of $\sqrt{s^2}$ naturally arise, several steps are taken. First, $\exp[-R_{\text{tot}}\theta/2x_L]$ is factored from all possible terms. Simultaneously, terms containing $1/\sqrt{s^2}$ are segregated from terms in which lead coefficients containing $\sqrt{s^2}$ do not appear.

$$\begin{aligned}
 I_2 = & \frac{V_D}{Z_0} \cos(\theta - (\theta_0 + \gamma)) \\
 & + \exp\left[-\frac{R_{\text{tot}}}{2x_L}\right] \left[\left(\frac{V_D}{Z_0 \sqrt{s^2}} \right) \left(\frac{R_{\text{tot}}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) \right. \\
 & - \frac{1}{\sqrt{s^2}} \left(V_0 + \frac{R_{\text{tot}} I_0}{2} \right) - \frac{V_D}{2Z_0} \cos(\theta_0 + \gamma) + \frac{I_0}{2} \exp\left[\frac{\sqrt{s^2} \theta}{2x_L}\right] \\
 & - \left(\frac{V_D}{Z_0 \sqrt{s^2}} \right) \left(\frac{R_{\text{tot}}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) - \frac{1}{\sqrt{s^2}} \left(V_0 + \frac{R_{\text{tot}} I_0}{2} \right) \\
 & \left. + \frac{V_D}{2Z_0} \cos(\theta_0 + \gamma) - \frac{I_0}{2} \exp\left[-\frac{\sqrt{s^2} \theta}{2x_L}\right] \right] \quad (C-68)
 \end{aligned}$$

Now like terms of $\exp[\sqrt{s^2}\theta/2x_L]$ and $\exp[-\sqrt{s^2}\theta/2x_L]$ are combined, then segregated so that terms in

$\exp[\sqrt{s^2}/2x_L] + \exp[-\sqrt{s^2}/2x_L]$ are separate from terms in $\exp[\sqrt{s^2}/2x_L] - \exp[-\sqrt{s^2}/2x_L]$.

$$\begin{aligned}
 I_2 = & \frac{V_p}{z_0} \cos(\theta - (\theta_0 + \gamma)) \\
 & + \exp\left[-\frac{R_{\text{tot}}}{2x_L}\right] \left[\left\{ \frac{V_p}{z_0} \left(-\frac{R_{\text{tot}}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) \right. \right. \\
 & \left. \left. - \left(V_0 + \frac{R_{\text{tot}} I_0}{2} \right) \right\} \frac{\exp\left[\frac{\sqrt{s^2}}{2x_L} \theta\right] - \exp\left[-\frac{\sqrt{s^2}}{2x_L} \theta\right]}{\sqrt{s^2}} \right. \\
 & \left. + \left\{ \frac{I_0}{2} - \frac{V_p}{2z_0} \cos(\theta_0 + \gamma) \right\} \frac{\exp\left[\frac{\sqrt{s^2}}{2x_L} \theta\right] + \exp\left[-\frac{\sqrt{s^2}}{2x_L} \theta\right]}{1} \right]. \quad (C-69)
 \end{aligned}$$

Recall

$$\frac{e^x + e^{-x}}{2} = \cosh x, \text{ the hyperbolic cosine}$$

$$\frac{e^x - e^{-x}}{2} = \sinh x, \text{ the hyperbolic sine}$$

$$\frac{e^{jx} + e^{-jx}}{2} = \cos x$$

$$\frac{e^{jx} - e^{-jx}}{2j} = \sin x$$

where $j = \sqrt{-1}$. If x is pure imaginary, $\cosh x = \cos(x/j)$, and $\sinh x = (1/j) \sin(x/j)$. The point is that hyperbolic and ordinary trigonometric functions may be regarded as essentially

the same provided a suitable method exists for handling $\sqrt{-1}$. An overdamped or underdamped circuit ($s^2 > 0$ and $s^2 < 0$ respectively) are identically described if only a convenient method for expressing hyperbolic sines and cosines with a single function can be found. This is simple if one's computational device handles complex numbers routinely--Equation (C-69) can be directly applied. If only real numbers are to be used, the following definitions allow manipulation of the exponentials, independent of s^2 :

$$\text{ccosh}(\sqrt{s^2} \cdot x) = \cosh(\sqrt{|s^2|} \cdot x), \quad s^2 \geq 0 \quad (\text{C-70})$$

$$= \cos(\sqrt{|s^2|} \cdot x), \quad s^2 \leq 0 \quad (\text{C-71})$$

$$\text{csinh}(\sqrt{s^2} \cdot x) = \frac{\sinh(\sqrt{|s^2|} \cdot x)}{\sqrt{|s^2|}}, \quad s^2 \geq 0 \quad (\text{C-72})$$

$$= \frac{\sin(\sqrt{|s^2|} \cdot x)}{\sqrt{|s^2|}}, \quad s^2 \leq 0. \quad (\text{C-73})$$

The author knows of no previous definition of these functions explicitly. Several sources, listed with comments at the end of this appendix, do however hint at either these functions or at the approach given in this appendix for unified solution of the series R-L-C circuit. At $s^2 = 0$, $\text{ccosh}(\sqrt{s^2} \cdot x) = 1$; $\text{csinh}(\sqrt{s^2} \cdot x) = x$. These limits may be derived from any of the Eqs. (C-70)-(C-73) by series expanding the exponentials, summing the terms, and then taking the limit as $s^2 \rightarrow 0$. Note that throughout the derivation,

$\sqrt{s^2}$ has been used in place of s so that the absolute value could be used with the complex hyperbolic functions. Inserting the appropriate factor of 2 in the denominators of the exponential terms in Equation (C-69) and applying the definitions of the hyperbolic functions, the final form of I_2 is found:

$$\begin{aligned}
 I_2 = & \frac{V_p}{z_0} \cos(\theta - (\theta_0 + \gamma)) \\
 & + \exp\left[-\frac{-R_{tot}\theta}{2x_L}\right] \left[\left\{ \frac{V_p}{z_0} (R_{tot} \cos(\theta_0 + \gamma) - 2x_C \sin(\theta_0 + \gamma)) \right. \right. \\
 & \quad \left. \left. - (2V_0 + I_0 R_{tot}) \right\} \cdot \text{csinhd}\left(\sqrt{s^2} \cdot \frac{\theta}{2x_L}\right) \right. \\
 & \quad \left. + \left\{ I_0 - \frac{V_p}{z_0} \cos(\theta_0 + \gamma) \right\} \cdot \text{ccosh}\left(\sqrt{s^2} \cdot \frac{\theta}{2x_L}\right) \right] .
 \end{aligned} \tag{C-74}$$

V_C is determined by taking Equation (C-51), regrouping terms, inserting values for A_1 and A_2 , and applying the same types of rearrangements as used to obtain I_2 . After performing these steps, several more manipulations, to be given below, give a final closed form for V_C . Starting from Equation (C-51):

$$\begin{aligned}
 V_C = & V_p \cos(\theta - \theta_0) - \frac{V_p R_{tot}}{z_0} \cos(\theta - (\theta_0 + \gamma)) + \frac{V_p x_L}{z_0} \sin(\theta - (\theta_0 + \gamma)) \\
 & - A_1 \left(R_{tot} + x_L \left(\frac{-R_{tot} + \sqrt{s^2}}{2x_L} \right) \right) \exp\left[\frac{-R_{tot} + \sqrt{s^2}}{2x_L} \theta \right] \\
 & - A_2 \left(R_{tot} + x_L \left(\frac{-R_{tot} - \sqrt{s^2}}{2x_L} \right) \right) \exp\left[\frac{-R_{tot} - \sqrt{s^2}}{2x_L} \theta \right] .
 \end{aligned} \tag{C-51} \text{ Restated}$$

Dealing first with the trigonometric terms, the first three in Equation (C-51) as restated, one proceeds:

$$\begin{aligned}
 & V_p \cos(\theta - \theta_0) - \frac{V_p R_{tot}}{z_0} \cos(\theta - (\theta_0 + \gamma)) + \frac{V_p x_L}{z_0} \sin(\theta - (\theta_0 + \gamma)) \\
 &= V_p [\cos\theta \cos\theta_0 + \sin\theta \sin\theta_0 - \cos\gamma \cos(\theta - (\theta_0 + \gamma))] \\
 &+ \left(\frac{x_L - x_C}{z_0} + \frac{x_C}{z_0} \right) \sin(\theta - (\theta_0 + \gamma))] \quad (C-75)
 \end{aligned}$$

$$\begin{aligned}
 &= V_p [\cos\theta \cos\theta_0 + \sin\theta \sin\theta_0 - \cos\gamma (\cos\theta \cos(\theta_0 + \gamma) + \sin\theta \sin(\theta_0 + \gamma)) \\
 &+ \frac{x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) + \sin\gamma (\sin\theta \cos(\theta_0 + \gamma) - \cos\theta \sin(\theta_0 + \gamma))] \quad (C-76)
 \end{aligned}$$

$$\begin{aligned}
 &= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) + V_p [\cos\theta \cos\theta_0 + \sin\theta \sin\theta_0 \\
 &- \cos\gamma (\cos\theta (\cos\theta_0 \cos\gamma - \sin\theta_0 \sin\gamma) + \sin\theta (\sin\theta_0 \cos\gamma + \cos\theta_0 \sin\gamma)) \\
 &+ \sin\gamma (\sin\theta (\cos\theta_0 \cos\gamma - \sin\theta_0 \sin\gamma) - \cos\theta (\sin\theta_0 \cos\gamma + \cos\theta_0 \sin\gamma))] \quad (C-77)
 \end{aligned}$$

$$\begin{aligned}
 &= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) + V_p [\cos\theta \cos\theta_0 + \sin\theta \sin\theta_0 - \cos^2\gamma \cos\theta \cos\theta_0 \\
 &+ \cos\gamma \sin\gamma \cos\theta \sin\theta_0 - \cos^2\gamma \sin\theta \sin\theta_0 - \cos\gamma \sin\gamma \sin\theta \cos\theta_0 \\
 &+ \sin\gamma \cos\gamma \sin\theta \cos\theta_0 - \sin^2\gamma \sin\theta \sin\theta_0 - \sin\gamma \cos\gamma \cos\theta \sin\theta_0 \\
 &- \sin^2\gamma \cos\theta \cos\theta_0] \quad (C-78)
 \end{aligned}$$

$$\begin{aligned}
 &= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) + V_p [\cos \theta \cos \theta_0 + \sin \theta \sin \theta_0 \\
 &\quad - (\cos^2 \gamma + \sin^2 \gamma) \cos \theta \cos \theta_0 - (\cos^2 \gamma + \sin^2 \gamma) \sin \theta \sin \theta_0]
 \end{aligned}
 \tag{C-79}$$

$$= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma))
 \tag{C-80}$$

where the identity $\cos^2 \gamma + \sin^2 \gamma = 1$ has been used. So

$$\begin{aligned}
 V_C &= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) - A_1 \left(\frac{R_{\text{tot}} + \sqrt{s^2}}{2} \right) \exp \left[\frac{-R_{\text{tot}} + \sqrt{s^2}}{2x_L} \theta \right] \\
 &\quad - A_2 \left(\frac{R_{\text{tot}} - \sqrt{s^2}}{2} \right) \exp \left[\frac{-R_{\text{tot}} - \sqrt{s^2}}{2x_L} \theta \right] .
 \end{aligned}
 \tag{C-81}$$

Now A_1 and A_2 may be inserted.

$$\begin{aligned}
 V_C &= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) \\
 &\quad - \left(\frac{V_p}{z_0 \sqrt{s^2}} \left(\frac{R_{\text{tot}} - \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) \right. \\
 &\quad \left. - \frac{V_0 + \frac{R_{\text{tot}} - \sqrt{s^2}}{2} I_0}{\sqrt{s^2}} \right) \frac{R_{\text{tot}} + \sqrt{s^2}}{2} \exp \left[\frac{-R_{\text{tot}} + \sqrt{s^2}}{2x_L} \theta \right] \\
 &\quad + \left(\frac{V_p}{z_0 \sqrt{s^2}} \left(\frac{R_{\text{tot}} + \sqrt{s^2}}{2} \cos(\theta_0 + \gamma) - x_C \sin(\theta_0 + \gamma) \right) \right. \\
 &\quad \left. - \frac{V_0 + \frac{I_0}{2} (R_{\text{tot}} + \sqrt{s^2})}{\sqrt{s^2}} \right) \frac{R_{\text{tot}} - \sqrt{s^2}}{2} \exp \left[\frac{-R_{\text{tot}} - \sqrt{s^2}}{2x_L} \theta \right] .
 \end{aligned}
 \tag{C-82}$$

First, the $R_{\text{tot}} \pm \sqrt{s^2}$ terms associated with the exponentials are propagated through the full coefficients of the exponentials:

$$\begin{aligned}
 V_C = & \frac{V_P x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) \\
 & - \left(\frac{V_P}{z_0 \sqrt{s^2}} \left(\frac{R_{\text{tot}}^2 - s^2}{2} \cos(\theta_0 + \gamma) - x_C (R_{\text{tot}} + \sqrt{s^2}) \sin(\theta_0 + \gamma) \right) \right. \\
 & - \frac{V_0 (R_{\text{tot}} + \sqrt{s^2}) + \frac{I_0}{2} (R_{\text{tot}}^2 - s^2)}{\sqrt{s^2}} \left. \right) \left(\exp \left[\frac{-R_{\text{tot}} + \sqrt{s^2}}{2x_L} \theta \right] \right) / 2 \quad (C-83) \\
 & + \left(\frac{V_P}{z_0 \sqrt{s^2}} \left(\frac{R_{\text{tot}}^2 - s^2}{2} \cos(\theta_0 + \gamma) - x_C (R_{\text{tot}} - \sqrt{s^2}) \sin(\theta_0 + \gamma) \right) \right. \\
 & - \frac{V_0 (R_{\text{tot}} - \sqrt{s^2}) + \frac{I_0}{2} (R_{\text{tot}}^2 - s^2)}{\sqrt{s^2}} \left. \right) \left(\exp \left[\frac{-R_{\text{tot}} - \sqrt{s^2}}{2x_L} \theta \right] \right) / 2 \} .
 \end{aligned}$$

Next, factor out $\exp[-R_{\text{tot}} \theta / 2x_L]$ and insert the definition of s^2 (here is another reason to use $\sqrt{s^2}$ in place of s throughout)

$$\begin{aligned}
V_C &= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) - \exp\left[-\frac{R_{tot} \theta}{2x_L}\right] \\
&\cdot \left\{ \left[\frac{V_p}{z_0 \sqrt{s^2}} (2x_L x_C \cos(\theta_0 + \gamma) - x_C (R_{tot} + \sqrt{s^2}) \sin(\theta_0 + \gamma)) \right. \right. \\
&\quad \left. \left. - \frac{V_0 (R_{tot} + \sqrt{s^2}) + 2x_L x_C I_0}{\sqrt{s^2}} \right] (\exp\left[\frac{\sqrt{s^2} \theta}{2x_L}\right]) / 2 \right. \\
&\quad \left. - \left[\frac{V_p}{z_0 \sqrt{s^2}} (2x_L x_C \cos(\theta_0 + \gamma) - x_C (R_{tot} - \sqrt{s^2}) \sin(\theta_0 + \gamma)) \right. \right. \\
&\quad \left. \left. - \frac{V_0 (R_{tot} - \sqrt{s^2}) + 2x_L x_C I_0}{\sqrt{s^2}} \right] (\exp\left[-\frac{\sqrt{s^2} \theta}{2x_L}\right]) / 2 \right\} .
\end{aligned} \tag{C-84}$$

As performed previously in finding I_2 , group the exponentials in such a way as to form hyperbolic trigonometric functions:

$$\begin{aligned}
V_C &= \frac{V_p x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) - \exp\left[-\frac{R_{tot} \theta}{2x_L}\right] \\
&\times \left\{ \frac{1}{2} (\exp\left[\frac{\sqrt{s^2} \theta}{2x_L}\right] + \exp\left[-\frac{\sqrt{s^2} \theta}{2x_L}\right]) \left(-V_0 - \frac{V_p x_C}{z_0} \sin(\theta_0 + \gamma) \right) \right. \\
&\quad \left. + \frac{1}{2} (\exp\left[\frac{\sqrt{s^2} \theta}{2x_L}\right] - \exp\left[-\frac{\sqrt{s^2} \theta}{2x_L}\right]) \right. \\
&\quad \times \left(\frac{V_p}{z_0 \sqrt{s^2}} (2x_L x_C \cos(\theta_0 + \gamma) - x_C R_{tot} \sin(\theta_0 + \gamma)) \right. \\
&\quad \left. \left. - \left(\frac{V_0 R_{tot}}{\sqrt{s^2}} + \frac{2x_L x_C I_0}{\sqrt{s^2}} \right) \right) \right\} .
\end{aligned} \tag{C-85}$$

A more convenient sign convention replaces the minus sign preceding the exponential with a plus sign and propagates the change through the equation. Further, $\sqrt{s^2}$ may be factored from the second group of terms giving the csinhd function:

$$\begin{aligned}
 V_C = & \frac{V_D x_C}{z_0} \sin(\theta - (\theta_0 + \gamma)) + \exp\left[\frac{-R_{\text{tot}} \theta}{2x_L}\right] \\
 & \times \left\{ \cosh(\sqrt{s^2} \frac{\theta}{2x_L}) \cdot (V_0 + \frac{V_D x_C}{z_0} \sin(\theta_0 + \gamma)) \right. \\
 & + \text{csinhd}(\sqrt{s^2} \frac{\theta}{2x_L}) \cdot (\frac{V_D}{z_0} (x_C R_{\text{tot}} \sin(\theta_0 + \gamma) - 2x_L x_C \cos(\theta_0 + \gamma)) \\
 & \left. + (V_0 R_{\text{tot}} + 2x_L x_C I_0)) \right\} .
 \end{aligned} \tag{C-86}$$

In Equations (C-17) and (C-20) it was shown that V_C is proportional to x_C . This is shown explicitly in the final form to be used for calculating V_C :

$$\begin{aligned}
 V_C = & x_C \left\{ \frac{V_D}{z_0} \sin(\theta - (\theta_0 + \gamma)) \right. \\
 & + \exp\left[\frac{-R_{\text{tot}} \theta}{2x_L}\right] \cdot \left[\cosh(\sqrt{s^2} \frac{\theta}{2x_L}) \cdot (\frac{V_0}{x_C} + \frac{V_D}{z_0} \sin(\theta_0 + \gamma)) \right. \\
 & + \text{csinhd}(\sqrt{s^2} \frac{\theta}{2x_L}) \cdot (\frac{V_D}{z_0} (R_{\text{tot}} \sin(\theta_0 + \gamma) - 2x_L \cos(\theta_0 + \gamma)) \\
 & \left. \left. + (\frac{V_0 R_{\text{tot}}}{x_C} + 2x_L I_0)) \right] \right\} .
 \end{aligned} \tag{C-87}$$

Equations (C-74) and (C-87) are the equations sought for describing capacitor charging. While other forms of the solution exist and may in certain computational situations be of utility, further discussion and calculation will employ the forms shown.

III. Application of Equations to Spark Source Operation

Use of the above equations to predict or understand spark source operation is dependent on two implementation steps: (1) design of computational routines and (2) selection of experimental parameters.

The equations derived above present evaluation problems mainly for R_{tot} large and $R_{\text{tot}} \approx \sqrt{s^2}$. In this situation, $\cosh(\sqrt{s^2}(\theta/2x_L))$ is evaluated as $\cosh(\sqrt{s^2}(\theta/2x_L))$ and $\text{csinh}(\sqrt{s^2}(\theta/2x_L))$ is evaluated as $\sinh(\sqrt{s^2}(\theta/2x_L))/\sqrt{s^2}$. For large x (x is any argument for the functions, not just those which apply to this problem), $\sinh(x) \approx \cosh(x)$. If $\sqrt{s^2} \theta/2x_L > 10$, $\exp[\sqrt{s^2} \theta/2x_L] = \cosh(\sqrt{s^2} \theta/2x_L)$ within five parts in 10^9 ; as the Univac 1110 computer employed maintains only eight significant figures, this difference is insignificant. Thus round off errors due to taking large differences between small numbers and outright overflows when $\exp[\sqrt{s^2} \theta/2x_L] > 10^{38}$ can be avoided by combining the hyperbolic functions with the lead exponential term. This is done only for $(\sqrt{s^2} \theta/2x_L) > 10$, $s^2 > 0$. Equations (C-74) and (C-87) then become:

$$\begin{aligned}
 I_2 = & \frac{V_D}{z_0} \cos(\theta - (\theta_0 + \gamma)) + (\exp[-\frac{\sqrt{s^2} - R_{tot}}{2x_L} \theta]) / 2 \\
 & \times \{ \frac{1}{\sqrt{s^2}} (\frac{V_D}{z_0} (R_{tot} \cos(\theta_0 + \gamma) - 2x_C \sin(\theta_0 + \gamma)) - (2V_0 + I_0 R_{tot})) \\
 & + I_0 - \frac{V_D}{z_0} \cos(\theta_0 + \gamma) \} \quad (C-88)
 \end{aligned}$$

$$\begin{aligned}
 V_C = & x_C \{ \frac{V_D}{z_0} \sin(\theta - (\theta_0 + \gamma)) + (\exp[-\frac{\sqrt{s^2} - R_{tot}}{2x_L} \theta]) / 2 \\
 & \times [\frac{V_D}{x_C} + \frac{V_D}{z_0} \sin(\theta_0 + \gamma) + \frac{1}{\sqrt{s^2}} (\frac{V_D}{z_0} (R_{tot} \sin(\theta_0 + \gamma) - 2x_L \cos(\theta_0 + \gamma)) \\
 & + \frac{V_0 R_{tot}}{x_C} + 2x_L I_0) \} \}. \quad (C-89)
 \end{aligned}$$

As Equations (C-88) and (C-89) apply mainly when $\sqrt{s^2} \approx R_{tot}$, the limited precision of the computer results in round off error if $\sqrt{s^2}$ is directly evaluated. If $|(\sqrt{s^2} - R_{tot})/R_{tot}| < 1 \cdot 10^{-3}$, $\sqrt{s^2}$ can be series expanded about $x_L \cdot x_C = 0$ to give

$$\sqrt{s^2} \approx R_{tot} (1 - \frac{4x_L x_C}{R_{tot}^2} (0.5 + \frac{x_L x_C}{2R_{tot}^2})) \quad (C-90)$$

to five parts in 10^4 or better. A simpler formula for computation is:

$$\sqrt{s^2} - R_{tot} \approx - \frac{4x_L x_C}{R_{tot}^2} (0.5 + \frac{x_L x_C}{2R_{tot}^2}) \quad (C-91)$$

At this point the mechanics of algorithm implementation becomes intertwined with two considerations: (a) efficient software structure and coding and (b) setting of parameters to match source operation. While these are not separable, (a) will be dealt with first.

Several constants are entirely independent of break pattern and depend only on circuit parameters. These are the constants derived from R_{tot} , L , C , V_p , and ω . R_{tot} does depend on the bias condition of the diode, but, to a first approximation, need be set only at the start of charging in either a forward biased or reverse biased mode. The time independent constants are x_L , x_C , s^2 , $\sqrt{s^2}$, γ , $\sqrt{s^2} - R_{tot}$, z_0 , and V_p/z_0 , and may be stored in memory before any break information is processed. A feature not included in present software but which may be useful is to calculate all these constants for both forward-biased diode and reverse-biased diode conditions, and store them sequentially rather than alternately as they are applied.

Charging "starts" any time a circuit parameter changes. Such times are: (a) start of a half-cycle; (b) instant of discharge; (c) completion of discharge; (d) change in bias condition of the diode. In each case R_{tot} , C , θ_0 , I_0 , and V_0 must be set to match conditions in the source, and any indefinite terms in the equations assigned appropriate values. θ_0 is always set with reference to the peak in the transformer voltage such that θ_0 at the beginning of a half-cycle is $-\pi/2$, at the end of the

half-cycle is $\pi/2$, and assumes intermediate values in between. If $t_0 = 0$ is set at peak transformer voltage, $t_0 = 4166.7 \mu s$ at the end of the half-cycle, and so on

$$\theta_0 = 2\pi f t_0 \quad (C-92)$$

or if t'_0 is set so $t'_0 = 0$ at the beginning of the half-cycle and $= 8333.3 \mu s$ at the end of the half-cycle then

$$\theta_0 = 2\pi f (t'_0 - 4166.7 \cdot 10^{-6} \text{ sec.}) \quad (C-93)$$

V_0 and I_0 are taken as the voltage and current on or through the capacitor at the end of the preceding charging interval, except as noted below. Thus all parameters in the equations are given except θ . $\theta = 2\pi f t$, where t is the elapsed time since the last time θ_0 was set. So once θ_0 is given, varying θ follows the course of the charging.

When I is ≤ 0 , it is assumed the diodes are reverse-biased. When $I \geq 0$, it is assumed they are forward-biased. Simply by checking the present value of I and what the bias condition is, changes in diode conduction state can be identified.

The full-wave rectified nature of the drive waveform is accounted for by resetting θ_0 to $-\pi/2$ at the start of each half-cycle, rather than allowing it to exceed $\pi/2$ as it would

in a nonrectified circuit. A counter prevents $\theta_0 + \theta$ from exceeding $\pi/2$ as well.

The only situation left to be explained is the charging circuit's behavior during a discharge. The physical model was described in the body of this thesis, in which it was pointed out that the discharge duration t_d for the purposes of modeling is one-half the on-time of the thyatron/diode network. During this discharge time

$$x_C = C = 0. \quad (C-94)$$

This implies, in the above equations, that

$$V_0 = V_C = 0 \quad (C-95)$$

and

$$\frac{V_0}{x_C} = 2\pi f C V_0 = 0. \quad (C-96)$$

Thus during the period of discharge, the original Equations (C-74) and (C-87) hold, using (C-94)-(C-96) for setting parameters.

Given the source parameters and appropriate initial conditions, the only independent variable which changes during charging is θ . Inspection of Equations (C-74) and (C-87) reveals three types of terms containing θ : (a) a sinusoidal term, (b) $\exp[-R_{tot}^2/2x_L]$, and (c) the complex hyperbolic functions.

For computational convenience, various groups of constants may be evaluated at the beginning of a calculational sequence. One plausible arrangement for doing this will be discussed in Appendix D concerning the spark source modeling program.

IV. Comments on the Complex Hyperbolic Functions

Various aspects of the definition, use, and properties of the hyperbolic functions may be found as follows:

- (1) G. B. Thomas, Calculus and Analytic Geometry, 4th ed., Addison-Wesley Pub. Co. (Reading, Mass., 1969), or other freshman calculus text. Gives properties of $\sin$, $\cos$, $\sinh$, and $\cosh$ with real arguments.
- (2) Jon M. Smith, Scientific Analysis on the Pocket Calculator, John Wiley and Sons (New York, 1975).
An appendix shows the relationship of $\sin$ and $\sinh$, $\cos$ and $\cosh$, with complex arguments for each function. This shows how one can fluidly use either $\sin$ or $\sinh$, $\cos$ or $\cosh$ for calculation, provided one accepts $j (= \sqrt{-1})$ as an ordinary number with few unique properties. While this lack of unusual properties is not rigorously true, it is very useful!
- (3) E. J. Scott, Transform Calculus with an Introduction to Complex Variables, Harper and Row (New York, 1955).
For the case $I_0 = V_0 = 0$, Scott writes charging equations which use the classical concepts of

overdamped, underdamped, and critically damped. However, he only derives the underdamped case explicitly; the others he derives heuristically, inserting $\sinh$ and $\cosh$ in place of $\sin$ and $\cos$ functions as appropriate. Inspection of his results shows that, had he inserted one extra set of parentheses, he would have defined $\cosh$; all the terms are there, but not explicitly grouped.

Appendix D

PROGRAM FOR MODELING SPARK SOURCE CAPACITOR CHARGING

I. Introduction

This appendix describes both the theory and operation of a program (PITS--Programmable Independently Timed Spark source) for modeling the behavior of a capacitive discharge spark source whose main storage capacitor is charged by a rectified series R-L-C circuit. The justification for using such a model in many common sources was given in Appendix C.I. The program is coded in BASIC and has many features in common with other software discussed in this thesis. Specifically, a pinwheel structure similar to that used in the Abel Inversion software discussed in Appendix A is used, and plots produced with Pepsu (Appendix B) or Miniplot are available. Equations derived in Appendix C are coded into the program so that a wide variety of source charging characteristics and operating configurations may be modeled. Processes available include: time or voltage thresholding of discharge triggering, rectifier bridge diode commutation, parameter passing between half-cycles, parameter passing from charging based on one set of

initial conditions to that based on another set, and construction of a variety of source hardware properties and pattern melds which may be relevant to laboratory source operation. In short, all charging properties discussed in Chapter III may be modeled directly except for the "average current effect", and a printout of average current is given so that this phenomenon may be externally accounted for. Patterned intervals may be formed by melding sequential half-cycles.

PITS consists of four major sections: initialization, computation, output, and termination. When the program is first called, initialization is automatically the first routine accessed. Once initialization is completed, any routine may be accessed in any order. Up to four half-cycles of break patterns may be stored in memory at one time. Any number of half-cycles may be computed in sequence to make a control interval. This is done by outputting data relevant to each group of four half-cycles, and then continuing computations. Output may be any combination of printing and plotting desired, and an option is available to obtain hard copy printed output from runs made at a PEP terminal or other soft copy device.

The rest of this documentation is arranged as follows: First, the theory of operation of the computation section of the program is explained. This consists largely of taking theory developed in Chapter III and Appendix C and explaining the specific coding

implementation chosen for program PITS. Next, suggestions for effective modeling are given, so that input parameters to the program may be more easily chosen. A program listing, sample run, and variable list complete the documentation. Syntactical details for program use are given in both the "effective use" and "sample run" sections of the documentation.

II. Theory of Operation

Calculation routines are arranged in a combination of functions and subroutines so that the charging equations are efficiently evaluated and are tools of, rather than the focus of, the program. In the program listing, pages PITS-2, -3, and -4 can be seen to be a group of functions which lead to the evaluation of capacitor voltage and charging current. Functions are defined so as to evaluate the equations in stages.

The first function, FNP, evaluates charging parameters which are dependent only on hardware and are independent of time. These include impedances, ratios of peak transformer voltage to impedance, and the hardware phase angle γ . This function is evaluated any time R, L, or C change, which means any time diode bias changes or a discharge occurs (C becomes zero). Once these constants are evaluated, FNP is not called again until one of the relevant parameters changes i.e. when new initial conditions occur.

The next function is FNT, which calculates constants which are explicitly functions of time variable initial conditions. These include θ_0 , $\theta_0 + \gamma$, and all terms in the charging equations which involve the initial conditions I_0 and V_0 . At this point it becomes convenient to evaluate all parts of the charging equations ((C.74) and (C.87)) which do not have explicit time dependence, that is, dependence on θ . This was mentioned previously at the end of Appendix C.III. The coefficient of the csinhd term in the equation for capacitor voltage (equation (C.87)) is evaluated in line 107 of the program, BASIC statement 580. The ccosh coefficient for the voltage charging equation is evaluated in line 108, statement 585. Using the combined variables called T3 and T4 in the program, the voltage charging equation becomes:

$$V_C = X_C \left(\frac{V_0}{Z_0} \sin(\theta - (\theta_0 + \gamma)) - \exp\left(\frac{-R\theta}{2X_L}\right) \cdot (T3 \text{csinhd}(s^2, \frac{\theta}{2X_L}) - T4 \text{ccosh}(s^2, \frac{\theta}{2X_L})) \right) \quad (D.1)$$

(Note this result is used later in the program, but is written here to show what T3 and T4 represent.) The variable list at the end of this appendix will clarify how the various symbols in lines 107 and 108 can give the above result. Equation (D.1) is identical to equation (C.87) except that the coefficients of the complex hyperbolic functions have been compressed to a single symbol.

FNT also compresses the coefficients of the ccosh and csinh functions used in calculating charging current. These coefficients, called T6 and T5 respectively, are evaluated in listing lines 110, 112, and 113 (There are two possible formulas for T5 because capacitance may equal zero, and capacitance appears in the denominator of one of the formulas. By using an expression where $C = X_C = 0$ for the case where there is no capacitor in the circuit, division by zero is prevented, but a separate formula is necessary.). An equation similar in form to equation (D.1) and identical in meaning to equation (C.74) can then be written:

$$I = \frac{V}{Z_0} \cos(\theta - (\theta_0 + \gamma)) - \exp\left(\frac{-R\theta}{2X_L}\right) \cdot (T5 \cosh(s^2, \frac{\theta}{2X_L}) + T6 \cosh(s^2, \frac{\theta}{2X_L})) \quad (D.2)$$

The hyperbolic sine and cosine functions are evaluated in functions FNS and FNC from line 115 to 144. The argument A fed to each function corresponds to $\theta/2X_L$ in the above equations. S2 is $\sqrt{|s^2|}$.

Equation (D.2) is implemented in function FNI. Given the results of FNP and FNT, all that the calculation requires is evaluation of one cosine function, an exponential, and the two complex hyperbolic functions, followed by four multiplications and two additions. Similarly equation (D.1) is evaluated in function FNE. FNI gives charging current in milliamps, and FNE

gives capacitor voltage in volts. For the cases discussed in Appendix C.III where resistance is large and times are long so that equations (C.88) and (C.89) are applicable for current and voltage computation respectively, separate formulas for evaluating functions FNI and FNE are used (lines 161 and 179).

Thus it can be seen that all voltage and current evaluations can be performed between lines 54 and 182. The rest of the program consists of initialization, output and termination routines, and programming designed to feed times and initial conditions to the charging equations to be evaluated. In fact the rest of the program is written without specific reference to the details of the charging equations. Whenever a voltage or current is needed, a function call is executed (see for example lines 1562 and 1563). There are sufficiently many other concepts in the rest of the program that henceforth it is easiest if the equations are assumed to be black boxes which are fed hardware parameters and initial conditions, and return current and voltage. Attempting to look deeper into the equations while using them as evaluative tools in connection with source operation leads quickly to confusion, and an inability to keep the changing source conditions separate from the evaluation of current and voltage based on those conditions.

The next level of program operation is a series of functions and subroutines used to service various parts of the charging calculation routines. The first of these is a subroutine from

line 183 to line 200 which switches parameters and accesses FNP and FNT each time the bias condition of the rectifier bridge changes. To set up forward biased conditions, the routine is entered at statement 850, line number 188. To obtain reverse biased setup, entry is at statement 875, line 196. Thus a calling routine need only determine to which condition the diode is to be switched, and the correct entry point accessed.

Next is a linear interpolation routine, FNL. This function determines the abscissa of the point at which two curves intersect. Suppose there are two functions of x : $y(x)$ and $z(x)$. Define

$$y(x_1) = y_1 \quad y(x_2) = y_2 \quad z(x_1) = z_1 \quad z(x_2) = z_2. \quad (D.3)$$

If it can be ascertained that $y(x)$ intercepts $z(x)$ at an abscissa somewhere between x_1 and x_2 (call this abscissa x_0), then the value of x_0 should be computable by interpolation. Approximating $z(x)$ and $y(x)$ as straight lines, Figure D.1 shows the geometry which allows one to compute x_0 (by rearranging the equation given in the figure):

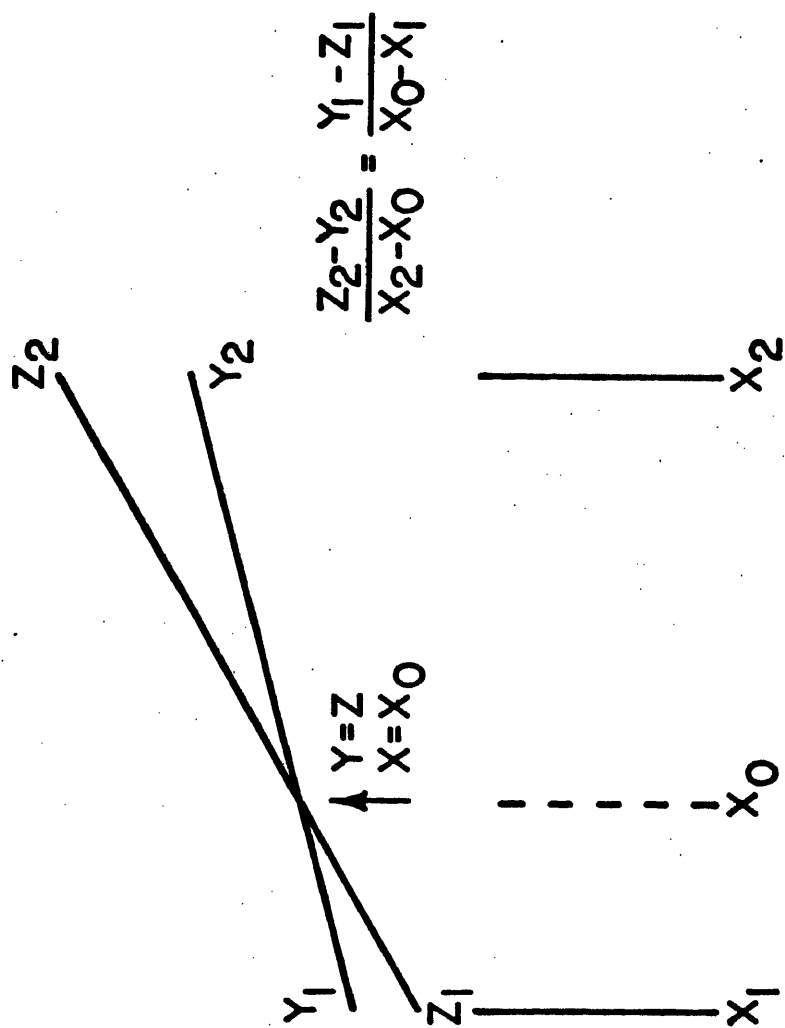
$$x_0 = \frac{x_2(z_1 - y_1) + x_1(y_2 - z_2)}{y_2 - z_2 + z_1 - y_1} \quad (D.4)$$

Replacing the symbol x_0 with the symbol FNL gives line 213, statement 960 in the program. By feeding the values of two points

Figure D.1

Interpolation Routine--geometry used to derive
interpolation formula.

$Y(x)$ and $Z(x)$ are approximated as straight lines.



which bracket the intercept point of the curves to the interpolation routine, an approximation to the intercept point is obtained. The other possible evaluation for FNL (statement 970, line 215) is applicable when $y(x)$ and $z(x)$ are in fact the same function. If $y(x) = z(x)$, then the denominator on the right side of equation (D.4) is 0, which leaves x_0 undefined. In this situation x_0 is assumed to lie halfway between x_1 and x_2 or

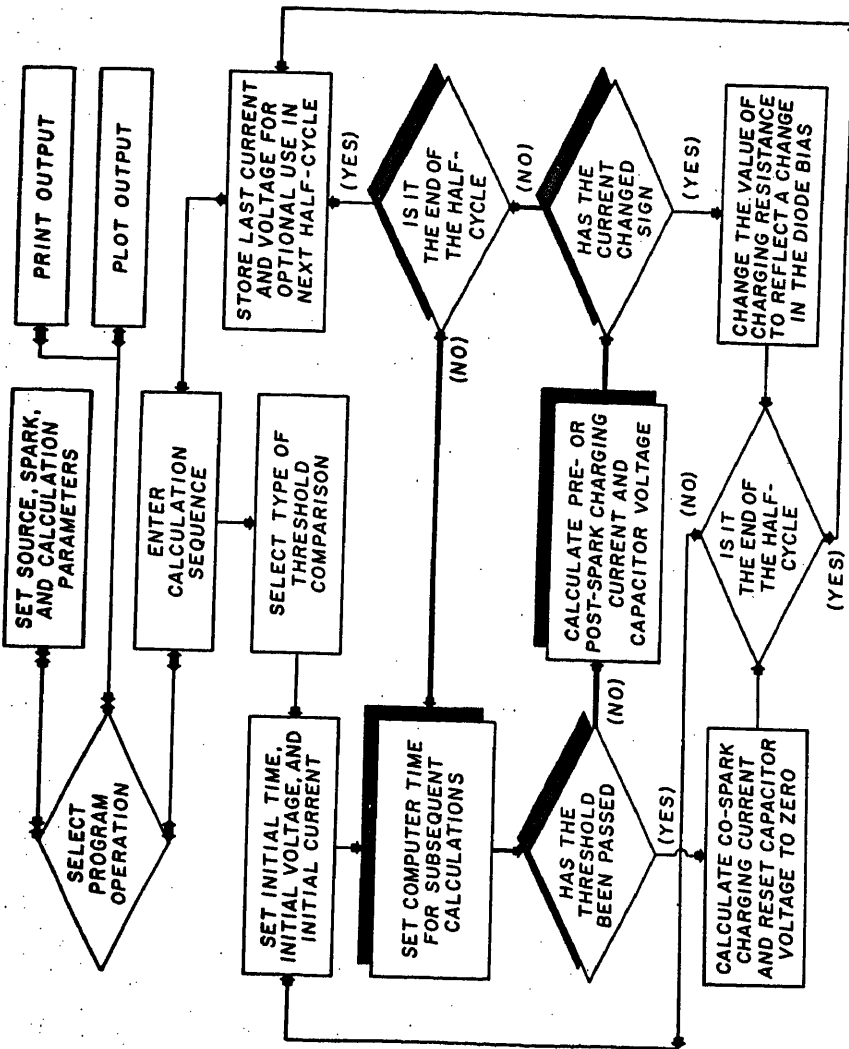
$$x_0 = \frac{x_1 + x_2}{2} . \quad (D.5)$$

FNL is applied to determination of diode commutation times and times of voltage threshold crossing. Charging voltages or charging currents are fed to the function for times just before and just after commutation or threshold crossing, and an interpolated time for the event in question returned.

Other subroutines and functions may most easily be understood after the flow of the computation routine is outlined. This is shown in Figure D.2. The heavily shaded blocks constitute the main flow of calculation of charging. Assuming all setup has been completed, the time at which voltage and current are to be computed is set and the values are computed. Three items are then checked. First, it is determined if the threshold condition has been passed for firing a discharge. That is, for time thresholding, is the time used for the voltage and current

Figure D.2

Flowchart for Program PITS



computation later than the time at which a given discharge in a train is to be fired? For voltage thresholding, did the charging curve pass through the thresholding manifold since the previously computed point? If so, control branches to a routine which computes co-spark charging. Otherwise, the second item is checked: Did the charging current change sign since the previous charging computation? If so, diode commutation has occurred. Control then branches to a routine to establish to $0.1 \mu\text{s}$ the time of diode commutation and to reset source conditions to reflect diode commutation. Otherwise, the third item is checked: Has the end of the half-cycle occurred? A data point is always calculated at $8333.3 \mu\text{s}$ elapsed time at the very end of the half-cycle. This corresponds to $\text{time} = 0$ for the ensuing half-cycle. If the end of the half-cycle has not occurred, time is incremented $50 \mu\text{s}$ and the calculation cycle repeats. Thus, calculation is a continuous cycle of: set time, compute voltage and current, check threshold, check diode bias, check end of half-cycle, and repeat, except when one of the three check points indicates alternative action is called for. All of the "alternative actions" amount to changing the value ascribed to some source parameter (resistance for diode commutation, capacitance for discharge occurrence) and the electrical and temporal initial conditions (I_0 , V_0 , θ_0).

Returning to the program listing, the places where each operation occurs will be described. The calculation routine is

entered at line 520, BASIC statement 4000. The thresholding mode is chosen, the half-cycle to be affected by computation is chosen (statement 4060, line 531), and initialization occurs (statement 4065, line 532). There are several ways in which initial conditions may be chosen, but these will be discussed at the end of this section in the context of melding patterns and passing parameters between half-cycles. Once initialization is completed, control branches to time (line 534) or voltage (line 536) thresholded charging routines.

The time thresholding routine appears on page PITS-14. The source of times is chosen as originating from a storage buffer associated with the present half-cycle ("this", the half-cycle selected in the routine called at line 531 above) or the previous half-cycle ("previous") i.e. the half-cycle numbered one lower than that chosen for computation. Otherwise the routine consists of setting or incrementing computed time (line 646, statement 6005), checking for time threshold passage (line 647), calling the normal voltage computation routine (648) or the co-spark computation routine (652), and continuing until the end of the half-cycle (line 650, statement 6020). Protection statements are provided (statements 6018 and 6025) to prevent overfilling internal storage.

The times to be used for thresholding may be inserted via the initialization routine or by previous computation via voltage

thresholding. If no initialization or previous computation has occurred, a zero breaks charging pattern will be computed.

Before the voltage thresholding routine can be explained, one more set of functions must be discussed. These appear on pages PITS-12 and -13. These functions form the manifolds describing various possible break patterns. FNR (lines 543 through 565) accesses information from the other functions, which are individual, choosable manifolds. Thus once the choice of manifold is made (via variable D2), all computations as to manifold voltage at some time T may be accessed from the rest of the program by a call to FNR.

Other functions and the manifolds they represent are as follows:

Function	Manifold
FNU	Individual discharge voltages as typed in during initialization form manifold.
FNV	Equivalent pattern manifold. Voltage chosen when manifold choice made.
FNW	Random pattern manifold. Break voltage varies randomly between 0 volts and some maximum value chosen when the manifold is chosen.
FNX	Sine pattern manifold. Both the amplitude and phase of the pattern with respect to line voltage are set when the pattern is chosen.
FNY	Ramp pattern manifold. Ramp voltage at the beginning and end of the half-cycle are specified at the time of manifold choice.

Function	Manifold
FNZ	This was originally intended for frequent user reprogramming into a variety of manifolds. It is presently set up as a trapezoidal pattern. The plateau voltage and times at which the plateau starts and stops are user specified. A user may define some other function by stating FNZ= (user chosen function) in the appropriate line numbers, and may use variables D3, D4, and D5 to pass information to the function. More details are given on function setup below.

The operation of the voltage thresholding routine may now be described. The first section of the routine is used to choose a manifold and supply the appropriate input parameters to specify that manifold. This occurs from line 1664 to line 1726, statements 16000 through 16310. If a user redefines function FNZ, the input parameters to that manifold may be supplied via an input routine running from statement number 16220 to number 16305 inclusive. This routine should accept all user input which is necessary to define the shape of the manifold, so that when the remaining software calls FNR, and thus indirectly FNZ, the manifold value at that time can be immediately accessed without active user input. Another useful point is that the parameter fed to FNZ, called T, is the time within a half-cycle referenced to the zero crossing. If the user's definition of FNZ depends only on input parameters and on time within the half-cycle, then the setup routine and other coding already present will feed FNZ correctly and well-defined voltages can be computed.

After input is accepted, the voltage thresholding routine defines how the first break of the half-cycle is to occur, and whether the calculations in general will account for limitations in hardware spark sources and their driving electronics. This input is obtained in statements 16315 through 16430 (lines 1727 through 1750).

The conformity control determines if hardware limitations will be accounted for, i.e. whether restrictions in hardware performance will be allowed to override the idealized procedure shown in the program flowchart. Restrictions were programmed to be those of the ADS 1800A computer/thyratron source combination discussed in Chapter III. Restricted operations are: (1) no firing allowed within 140 μ s of the beginning or end of a half-cycle, and (2) no two breaks closer together than 140 μ s.

The next two controls act to affect when the first discharge in the half-cycle is computed to occur. The first of these, the melding control, can be used to force a discharge to occur early in a half-cycle, whether or not the voltage at that time corresponds. If the initial voltage in a half-cycle is above the manifold voltage, it is possible that the voltage threshold will never be crossed. This may result in the computation of a zero break pattern. Should this occur, the pattern may be recomputed, using the "first break" (see below) or melding controls to fire a discharge early in the half-cycle to bring the capacitor voltage

below the manifold envelope. Note how the melding control can thus be used to link together otherwise incompatible manifolds in adjacent half-cycles, by "clearing out" high voltages "left over" on the capacitor at the beginning of the half-cycle.

The users choices, then, are to "fire a discharge at or near $\tau = 0$ " or to "fire discharge based only on the manifold." For brevity, call the first situation "melding control on" and the second situation "melding control off". In either case, the time at which the first break of the half-cycle occurs may be adjusted using the "first break" control.

The first break control allows the user to time threshold the initial break within a half-cycle. If the first break time is entered as "0", the control is "unset". If a positive time is entered (in microseconds, $0 < \text{time} \leq 8333$) then that is the time at which the first break occurs. When the first break control is set, the first break in the half-cycle is computed via time thresholding while all the rest are computed via voltage thresholding.

There are four combinations of setting of the melding and first break controls:

Melding off	First break unset	Manifold determines all break times. Pure voltage thresholding.
Melding off	First break set	First break time thresholded; otherwise voltage thresholded.

Melding on	First break unset	First break occurs at $t=0$ (or at $t=140 \mu s$ if hardware limited). Otherwise voltage thresholded.
Melding on	First break set	Same behavior as melding off/first break set.

From this it can be seen that the melding control is actually a means of providing a first break control without the user entering an explicit time. It is also apparent that there is a great deal of redundancy between the first break and melding controls. This did not become apparent until some time after the program was coded. If there is confusion as to the use of the two controls, it may be easiest to simply set the melding control "off" and either enter first break=0 when no time thresholded break is desired or first break=some positive number when an early time threshold or melding break is desired.

After the control flags are set, the voltage thresholding routine gets confirmation from the user that the setup is correct lines (1752-1755). If the first break is to be time thresholded, computation occurs accordingly. Once the initial conditions for the half-cycle have been set and any time thresholded break has been computed, normal voltage thresholded calculation begins at line 1775, statement 16530.

The remainder of the voltage thresholding routine increments the time within the half-cycle (line 1781), looks to see if the voltage threshold is past (1784-1788), and otherwise duplicates

the functioning of the time thresholded routine as outlined previously. When threshold crossing is detected, however, an iteration sequence occurs (lines 1793-1812) which terminates when charging voltage equals threshold voltage within 0.2 V. The time corresponding to this voltage is stored (line 1827, statement 16730) as the break time, after accounting for hardware limitations, and for the fact that the second (or n -th) break of a half-cycle must occur after the first (or $(n-1)$ -th) break.

The remainder of the voltage thresholding routine is involved with detecting diode commutation and preventing conflicts among breaks, diode commutation, and hardware limitations.

Routines have been mentioned but not described for commuting the diode, calculating co-spark charging, and terminating the half-cycle. These are written as part of the time thresholding routine in the 14000-15000 block of BASIC statements, and are referenced by means of subroutine calls from the voltage thresholding routine. Once the time of diode commutation has been established, either by the voltage or time thresholding routines, the setting of new initial conditions and resetting of resistance parameters is performed by a routine starting at line 1626 (statement 14675).

When a break is found, the time of that break is fed to a routine starting at line 1583 (statement 14465) which (a) sets capacitance to 0, (b) resets diode bias condition to "forward" if

it is not forward biased already, (c) computes charging current at the beginning and end of the break, (d) resets capacitance to its normal value, and (e) sets up initial conditions for the next normal inter-spark charging interval. The time of the end of the break is determined from the discharge duration typed in during initialization.

At the end of the half-cycle, lines 1616 through 1625 are executed to leave initial conditions for the next half-cycle, average current computation, and diode bias condition in appropriate order. Note that the diode is always left in forward biased condition even when this is not what was used for either the last computation in the given half-cycle nor would it be used with this bias for the first computation in the ensuing half-cycle. This is so that the bias condition is always known when a calculation is started and can be compared to a standard condition.

As can be seen from the above discussion, the linking of charging, discharging, diode bias conditions, and half-cycles is largely a matter of passing initial conditions from one set of charging computations to another. Storage registers are provided (see variable list) for the charging current and voltage at both the start and the end of a given half-cycle. At intermediate points in the half-cycle, parameters are passed through the arrays containing the full charging curve. For the situations where parameters are passed, values are as given in Table D.1. In

TABLE D.1. Parameters Passed As Initial Conditions. "As computed" means whatever θ_0 , I_0 , or V_0 are at the time new initial conditions are needed are the values used.

Situation	θ	θ_0	I_0	V_0	$C \cdot X_C$	R
Start of half-cycle	0	$-\pi/2$	Dependent on choice of initial conditions (lines 1470-1551)		Input value	Depends on sign of I_0
Start of discharge	0	$-\frac{\pi}{2} + 2\pi f t_d$	As computed	0	0	Forward biased value
End of discharge	0	$-\frac{\pi}{2} + 2\pi f (t_d + t_b)$	As computed	0	Input value	Forward biased value
Diode Commutation	0	As computed	0	As computed	Input value	Change from forward to reverse value or vice versa.
End of half-cycle	As computed	$\frac{\pi}{2}$	As computed	As computed	Input value	Depends on sign of I_0

f = line frequency (generally 60 Hz). t_d = time at which discharge occurs relative to zero crossing.
 t_b = duration of discharge.

large measure, this passing can be seen as (a) resetting θ to 0, (b) picking up the values of I and V_C present at the instant of passing and relabeling them as the new initial current I_0 and voltage V_0 , (c) setting θ_0 correctly and (d) changing R and C to fit with the charging condition of the capacitor and bias condition of the diodes. At the instant of parameter passing, θ is reset to 0, but $\theta + \theta_0$ remains constant. Thus, for example, the charging conditions at the end of a discharge are computed with $\theta = 2\pi f t_b$ and $\theta_0 = -(\pi/2) + 2\pi f t_d$. The current and voltage so computed are fed forward as initial conditions. θ is reset to zero, indicating that no time has elapsed since initial conditions were reset. θ_0 must also be reset to indicate elapsed time, since the zero crossing, at which initial conditions are being set. Initial conditions for the new charging interval were computed at the last point of the old charging interval, when θ_0 was a previous value, θ was positive and $\theta + \theta_0$ was some quantity θ_T . Because initial conditions are passed at a single instant, θ_T does not change in passing the conditions. θ goes from some positive number to 0, so

$$(\theta_0)_{\text{new conditions}} = (\theta_0)_{\text{old conditions}} + (\theta)_{\text{at last point of previous charging interval}} \quad (D.6)$$

At this juncture, the central points of the charging model are most clearly evident: (1) The R-L-C model of the circuit is assumed to hold regardless of specific component values or times.

(2) Differences in diode bias condition are accounted for by adjusting the value of resistance; discharge of the capacitor is accounted for by setting both capacitance and capacitive impedance to zero. (3) At the beginning of some charging interval, the values of R , C , θ_0 , I , and V_C are determined. Time is then incremented and time, voltage, and current values computed until some source parameter (R or C) changes. The old values of current and voltage are passed forward as new initial conditions, the parameters are reset, and θ_0 is adjusted so it corresponds to the time of the parameter switch. The sequence continues until the end of the half-cycle, at which point, due to the full wave rectified nature of the line voltage, θ_0 is reset to $-\pi/2$ and the whole process may be repeated. Aside from these three points, all of program PITS is either input/output routines, setup routines to feed the core charging algorithm, or details of executing the algorithm and determining when new initial conditions must be set.

III. Effective Program Use

Much of the syntactical use of the program is self-explanatory while the program is running. Many questions are worded: "There are two possible answers to this question: 'A' and 'B'. Input A or B?" If a legitimate response is not given, the question is reasked. In some instances, default answers are available which will allow the program to function without the user necessarily

understanding or controlling actively the effect of a particular option. Default options, when available, may be activated with the entry "-2". In some instances, the numeral 0 may be used as well, but this may prove confusing since 0 is also a nondefault answer possibility to some questions.

Herewith are some suggestions on how to use PITS for efficient calculation of break patterns. These should be regarded as starting points, as they reflect the style of usage of the author, rather than as absolute rules for running the program.

A. Initialization

On program startup, two questions are asked prior to the automatic calling of the initialization routine. These are: (a) "Do you want hard copy?" and (b) "What is power supply frequency--60 or 0.1 Hz?" If the first question is answered affirmatively, a copy of all print routine output will be made on a computing center line printer, thus preserving a hard record of a run at a "soft copy" device such as a PEP terminal. This is an expensive option, however. Default is to obtain hard copy. An alternative method for obtaining hard copy which includes ALL interaction, not just print routine output, will be discussed at the end of section III.C. The second question provides a method for simulating DC power supply operation of the spark source. At 0.1 Hz drive frequency, if the drive voltage is assumed to be at its peak when a "half-cycle" (actually in this instance, merely

a calculation interval of 8333.3 μ s) begins, the drive voltage will have remained constant within 0.002% at the end of the "half-cycle". No default exists. Sixty Hz charging has been tested and use more extensively than 0.1 Hz charging.

Initialization usage is summarized on listing page PITS-6. The reader is requested to read the boxed in documentation block on that page before continuing.

The options access various portions of the total initialization routine. Option 1 affects hardware R, L, and C values, option 2 affects peak transformer voltage, discharge duration, initial current, initial voltage, and initial time. Note that the only way to begin a charging computation under user control at a time other than the start of a half-cycle is by entering a time other than zero as the initial time in the initialization routine. In general, the entered value of initial voltage need not be zero. Peak transformer voltage or a voltage slightly higher than the break voltage of a desired equivalent break pattern may be appropriate. The closer the typed in initial voltage is to the voltage which will actually be on the capacitor between half-cycles in the midst of a patterned interval, the less time it will take to compute a precise break pattern.

Except in cases of high inductance, initial current in a half-cycle is small and may be given as 0 milliams.

Option 4 sets the maximum number of breaks computable per half-cycle and allows input of break times and voltages. The user may choose any maximum number of breaks up to 25 breaks, but may not choose zero breaks. Depending on the nature of the pattern desired, there are three common settings for the maximum number of breaks value.

- (1) For time thresholded operation, set max. breaks to 25. Typed in or otherwise computed times will indirectly limit the number of breaks to the number desired. Use time thresholding to compute a zero break pattern.
- (2) For voltage thresholded operation where the manifold shape is of great importance but the number of breaks per half-cycle is not of concern, set the max. breaks number to 25.
- (3) For voltage thresholded operation where some fixed number n breaks are desired per half-cycle, set the max. breaks number to that value n . This is the only way to force the number of breaks to be limited in voltage thresholded operation.

Break time and break voltage input allows user input of times for time thresholded operation, or individual break voltages for use in voltage thresholded operation. Input break voltages are nonvolatile; that is, the threshold voltages may be typed in at the beginning of a run, other computations performed, and the typed

in voltages will still be available for later computation. This is not the case for typed in times. The register used to store typed in times is rewritten each time a charging calculation is performed. Thus if time thresholding employing user input times is desired for half-cycle n , there can be no calculations performed on that half-cycle between the time the break times are typed in and the time they are employed. Computations involving other half-cycles can be performed, however.

When time and voltage input is solicited, one must specify for how many half-cycles input is to be made. If "1" is specified, the input will be to half-cycle one. If "2" is specified, input is to half-cycles one and two, etc. To be able to input break times or voltages to half-cycle 4, one must specify that input is to be made to all four half-cycles. It will be explained shortly how to skip over the data already present in one half-cycle in order to input data to a succeeding half-cycle.

It is legitimate to specify that 0 half-cycles of break time or break voltage data is to be input. If this is done, the time or voltage input routine is skipped.

Now the break time input will be specifically discussed. If the default "-2" is given in declaring the number of half-cycles of input times desired, all four half-cycles are set to give a break at 1000, 2000, ..., 8000 microseconds. When inputting specific break times within a half-cycle, specifying the default

generates a time of $1000n$ as the break time, where n is the number of the break (for the third break, the default time would be 3000 microseconds). The input times may be given in any order--they are automatically sorted in ascending order. After the last desired time has been entered, the user's desire to terminate input is indicated by entering a break time of 0 when solicited. Note that by entering 0 as the first break time, a zero break pattern is generated.

One other user choice, which is solicited before break times are specified, is whether a new list of break times is to be input or whether an old list of data is to be modified. "Fresh" input (also the default) clears out old break times within a half-cycle so that only the breaks times input during the present initialization call will appear for the given half-cycle. "Add to" input leaves old data in tact and allows addition of new break times to a preexisting list. By using "Add to" input, then specifying a break time of 0, one can effectively "skip over" a half-cycle where the old list of break times is to remain unchanged, in order to get to a half-cycle where changes are desired.

After a break time of "0" is entered, one may choose to edit break times (input "Yes", "Y", or "-2") or to continue with the next program operation (input "No", "N", "0", or "-1"). If editing is chosen, an opportunity is given to clear the screen

("Home is printed; the screen may be cleared, a character typed, and carriage return given to resume operation.), and the list of break times is printed out, with each break identified by a sequence number. The user may then delete break times not desired by specifying their sequence numbers. As many breaks as desired may be deleted. Deleting break 0 terminates the deletion routine. If the user is then satisfied with the break times input, he/she may continue to the next operation. If not, he/she may return to input more break times for the present half-cycle. To get a tabulation of the deletion-corrected times list, the user can claim not to be satisfied, input a new break time of 0, and get a fresh tabulation.

For the break voltage input routine, the initial choice is "Fresh" or "Edit". "Fresh" mode is similar to "Fresh" operation of the time thresholding routine except that data must be input in the order desired. Input voltages should be in volts. Again the digit 0 terminates Fresh input. After Fresh input is completed or when Edit mode is chosen, the user has a choice of leaving the voltage input routine ("Done"), inserting a new break voltage at an appropriate point in the voltage list ("Insert"), deleting a break voltage from the list ("Delete"), listing out the present input voltages ("List"), or returning to Fresh mode ("Fresh"). Both insertions and deletions should be performed one at a time, interspersed with listings of the break voltages.

Insertions and deletions change the sequence numbers of the breaks, and attempting to perform more than one insertion or deletion at a time may lead to confusion.

B. Calculation Routines

There are a number of subtle points concerning break pattern calculation which, when considered, can speed and ease program use. First to be considered will be the time thresholding routine. The control parameters which are supplied for this routine are:

- (1) the half-cycle upon which computation is to be performed,
- (2) the source of initial conditions for the computation, and (3) the source of break times for the thresholding routine. Computation may be performed on any of the four half-cycles. Default is half-cycle one. Using a half-cycle for which no break times have been supplied simply leads to a zero breaks charging pattern.

An aside may be helpful in understanding the paragraphs to follow. After charging computations are performed on a half-cycle, a number of parameters are saved in memory, including capacitor voltage and charging current at the end of the half-cycle, and the break times which were computed. These are available for later access during output or for use in later computations.

Initial conditions may come from one of three sources:

- (1) typed in input, (2) prior computations in the half-cycle being used for the present computation, or (3) the last data point of the previous half-cycle. "Typed in input" is the set of initial

conditions entered in the initialization routine. "Prior result in this half-cycle" takes the current and voltage computed as the last data point during a previous computational pass through the half-cycle of interest, and uses that as the initial conditions for the present pass. An application for this will be discussed momentarily. "Result of previous half-cycle" takes the last data point of the half-cycle numbered one lower than the present half-cycle, and uses the voltage and current therefrom as initial conditions for the present half-cycle. This is the mechanism by which one puts sequences of half-cycles together to form patterned intervals, by passing initial conditions sequentially from half-cycle to half-cycle. Just as in a hardware spark source, the initial conditions of succeeding half-cycles can be obtained by finding what the source conditions were at the end of the previous half-cycle.

Break times may be specified as originating either from a data bank associated with the half-cycle currently subject to computation, or from the bank associated with the previous half-cycle. If a particular set of break times have been typed in, or computed using an earlier pass of voltage thresholding, then the selection "this" for the source of half-cycle break times should be made. However, if one wishes to put together a patterned interval in which all half-cycles employ the same break times, it is often convenient to put those times in half-cycle one

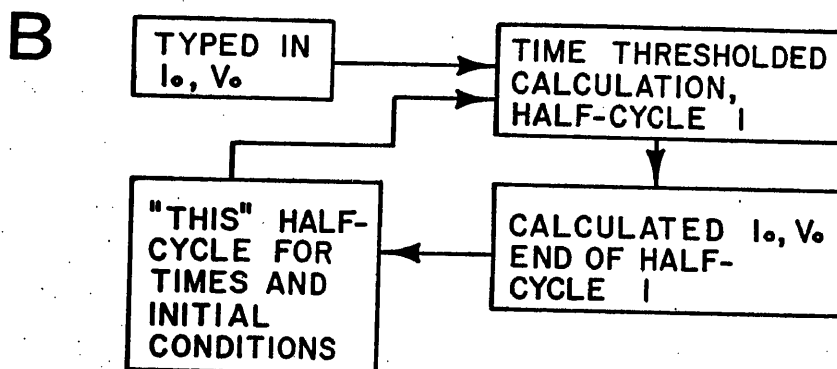
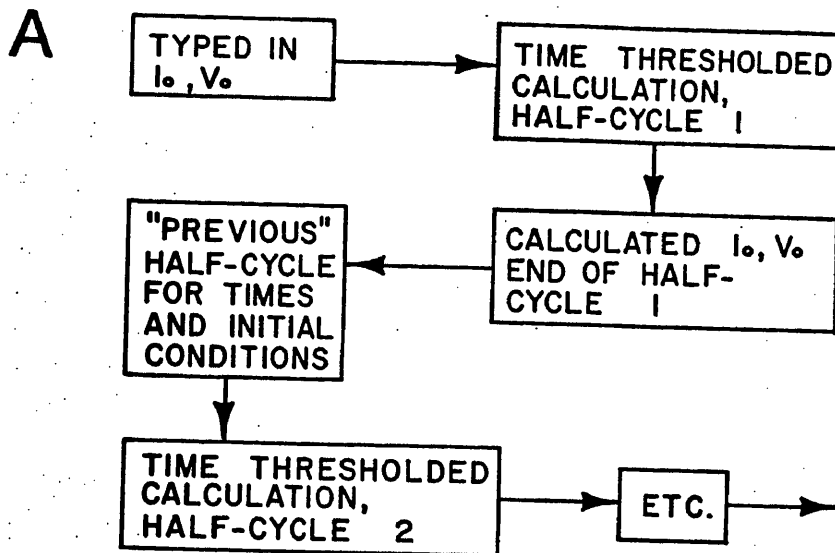
(by typed input or voltage thresholded computation) and then use "previous" as the source of break times in succeeding half-cycles to carry forward those break times for subsequent use.

To reiterate, voltage thresholding automatically overwrites typed in break times in a given half-cycle with the break times applicable to the voltage thresholded computation. Further, the "previous" half-cycle is indeed the half-cycle with the next lower number from the one undergoing computation--the previous half-cycle to half-cycle four is half-cycle three. The previous half-cycle for half-cycle one is half-cycle four, making it possible to put together control intervals of indefinitely great length (although output is limited to the four most recently computed half-cycles).

In all computations, it is advisable to iterate a pattern several times to determine the steady-state behavior of the system. There are two ways to do this for time thresholded computations as shown in Figure D.3. Inset A shows a method whereby the progress of the iteration can later be studied via a complete output of the pattern: Both break times and initial conditions are passed from one half-cycle to the next. After the computations are completed, four half-cycles of iteration may be output and the degree of convergence of the iteration examined. Another method is shown in Inset B. Here the results of one computational pass through a half-cycle are used again on the next pass. The only information available for output is the last

Figure D.3

Two Feasible Time Thresholding Iteration Sequences



iteration. Each of these two methods has its uses. Method A may be appropriate when novel combinations of source parameters are tested, as the process of pattern convergence may give an indication as to the stability of that particular combination of parameters and as to the need for iterative calculations during routine running. Further, until one has some idea of the number of iterations necessary for the charging algorithms to converge, it is inadvisable to blindly throw out the sequence of iteration calculations; this might result in incomplete iteration by a hurrying user. Method B may be used when the user is confident that sufficient iterations are indeed being performed, and a concise output is desired (one half-cycle only containing the final, stable break pattern). This method takes less time to use than Method A.

When using the voltage thresholding routine, many considerations are quite similar to those for using the time thresholding routine. However, because there are more variables, flags, and user controls, over the nature of the thresholding conditions, several extra points are in order.

When the voltage thresholding routine is called, the questions which must be answered are:

- (1) Which half-cycle is to be affected by computations?
- (2) What is the source of initial conditions?

(These two questions work in the same manner as they did in the time thresholding routine and will not be discussed further.)

- (3) Which manifold is to be used?
- (4) How should the conformity control be set?
- (5) How should the melding control be set?
- (6) How should the first break control be set?

In addition, the user is asked to confirm that the questions were answered to his satisfaction. If they were not, they may be reanswered prior to execution of the computations. Only an active answer of "Yes", "Y", or "-2" to the question of satisfaction with the setup will allow computation to procede.

There are six manifolds the user can choose. The arrangement of the question can be seen in Section V of this appendix, page EX-6. After a particular manifold is selected, in general other input is solicited. Note that for manifold 1, the voltages typed in during initialization are used, avoiding further input. Quantities needed for the other manifolds were listed earlier under function descriptions FNU through FNZ.

Answers to the other questions concerning voltage thresholding were also discussed above. By way of clarification, if the "First Break" time is entered as $\emptyset$, this corresponds to the control being unset. If a positive number is entered, this gives the time of the first break of the half-cycle.

An overall operating strategy will now be addressed. As discussed in Chapter III, voltage thresholding is an inherently

unstable computation. Thus to "iterate" a voltage thresholding calculation to obtain a stable pattern is not an efficient process. There are several procedures, however, which tend to stabilize the algorithm and still allow accurate matching of manifold shape. The first of these is to specify the time of the first break in the half-cycle. By time thresholding the first break, small accumulated differences between the desired and actual charging curves can be eliminated or at least dissipated in a known break (prior to the first break, presumably the diode is reverse biased, so that initial current effects are small and the "history" of the spark train leading up to the first break is only weakly carried forward to further breaks). This may be sufficient to allow voltage thresholded iteration to determine break patterns. Note that the melding control may also be used in this regard. A second technique that guarantees stability is to make one calculational pass using voltage thresholding, then doing iterations by time thresholding, using the times generated by the voltage thresholded calculations. Upon examination of the time thresholded output, some deviations from the desired pattern may be noted. If this is the case, either break times may be varied, source parameters adjusted, or a new voltage thresholded calculation performed. By interspersing time and voltage thresholded calculations, the instabilities of voltage thresholding are reduced or blocked entirely.

For both time thresholded and voltage thresholded calculations, the results must be corrected for the "average current effect" discussed in Chapter III. While there is no explicit means of doing this within the program, the average charging current during a half-cycle is available in the "parameter dump" in the printed output. Thus correction for the average current may be made externally without excessive difficulty.

C. Output Routines

There are three types of printed output and two types of plots available for outputting charging data. These may be mixed together to give a wide variety of output options. The options are tabulated in the documentation block at the beginning of the output routine in the program listing. See listing page PITS-15. PEPSUB is identical to the routine documented in Appendix B, except that all its inputs have been "hard wired" so that user input is unnecessary. MINILOT too gives output without the need for user direction. Scaling of plots is user controlled via a routine written especially for PITS. During a single output call, both MINILOT and PEPSUB may be accessed.

The printed output routine consists of three sections: (1) an option to print out the full charging curve, giving time, voltage, and current at each point; (2) an option to output only the break time, break voltage, and charging current at the instant of discharge firing; and (3) a "parameter dump" option to give a full

list of source conditions applicable during a given half-cycle, including capacitor voltage and charging current at the beginning and end of the half-cycle and average charging current during the half-cycle. If either of the first two printing options is called, the third automatically is invoked as well. On a single output call, one print option and one plot option may be executed. If both a print option and plot option are specified, the order of output is: (1) print options 1 or 2, (2) plot options, (3) print option 3. There may be omissions from this order due to option choice, but not permutations of the order. If both plots are requested in one option call, MINIPLOT executes before PEPSUB. If the user desires to set full scale on the plots, it is wise to get some sort of printout before attempting to plot.

At several places in the output routine (and elsewhere in the program as well), the query "Home?" appears. This gives the user an opportunity to clear the PEP terminal screen or advance to a fresh portion of teletype paper before continuing. When the question appears, the correct sequence of events is:

- (1) clear the screen or advance the paper.
- (2) type any letter or number; words may also be typed, but the extra characters are superfluous. Commas and periods should not be used.
- (3) Strike the return key and execution will resume.

If one does not wish to clear the screen, step (1) can be omitted without ill effect.

When the output routine is entered, the first item specified is the number of half-cycles to be output. If one half-cycle is output, that half-cycle is half-cycle one. Similarly, if two half-cycles are output, they are the first two. Up to four half-cycles may be output at once.

The next item to be input is a title. The title may not contain any commas, but otherwise may contain any symbols desired up to a maximum length of 60 characters. The default title is "Spark Pattern n" where n is a number, starting at 1 for the first output attempted.

Once the title has been given, one of two things happen: If only a print option was specified or if print options 1 or 2 were specified in concert with a plot option, printed output is produced. If only plotting is to occur or if plotting plus print option 3 are to be executed, plot setup occurs next.

Plot setup consists of setting two groups of parameters: (1) the variables to be plotted are selected and (2) the scaling to be used on the plots is selected. The three items which may be plotted are capacitor voltage, charging current, and transformer output voltage (rectified), with all three plotted as a function of time and any combination of items plottable simultaneously. When the program queries whether a particular item is to be plotted, a user response of "Yes" or "No" will select whether or not that item is plotted. The various plotted items are overlaid on each

other, with the program designed to automatically do the overlaying without user intervention. When more than one half-cycle is plotted, MINIPLOT outputs one half-cycle at a time. PEPSUB plots all the half-cycles concurrently; when hard copy is obtained, the dimensions of the plot are set so that the scale spacing on the time axis is unaffected by the number of half-cycles plotted.

The user also must specify a scaling option, as outlined in the documentation block on page PITS-15. Each of the options has its highlights and pitfalls. "-2" usage gives uniformly scaled plots (15 kV and 500 mA full scale) but may show little detail if low voltages or currents are being plotted. "1" (maximum datum = full scale) gives the maximum possible displayed detail, but each plot or group of plots made with one output routine call is scaled differently. "2", wherein the peak transformer voltage determines full scale, may be appropriate for uniform scaling, but may also result in losing information at the top of the plot when capacitor voltage exceeds peak transformer voltage (an example of this is shown in the sample run in Section V below). Finally, option 3 allows the user to set the full scale current and voltage; it is strongly recommended that some printed output be obtained before such scaling is set. Scales are expressed as volts (for full scale voltage) and as milliamps (for full scale current). For plot options 1 and 2, full scale for current is set

so that the plotted current fills only one-half of the vertical space available on the plot.

Other questions which may arise during plotting of output are (a) whether the user is satisfied with the plot setup and (b) on the first call to PEPSUB, whether hard copy plotting should be enabled. Both questions may be answered "Yes" or "No" as seems appropriate. If the user is unsatisfied with the plot setup, setup questions are repeated. For considerations on answering the PEPSUB hard copy question, see Appendix B.

Due to the restrictions of the graphics routines, both current and voltage scales cannot be written on the graph axes. If only one piece of information is plotted, this presents no problem and the correct vertical axis is labeled. If both current and voltage are plotted simultaneously, only the voltage scale gets printed on the graph--the current scale must be determined independently by the user. This presents little problem for options -2 and 3; in the former case, full scale is 500 mA, in the latter case whatever value the user chooses. For options 1 and 2, the only reliable way to determine scaling is to measure a current at some point on the plot and compare it to a tabulated value from the print routine.

The termination routine is intimately entwined with the output routine. If the program is terminated by typing "stop" instead of using the termination routine, all PEPSUB plotted

output may be lost, as well as hard copy printed output. When the termination routine is called, the user must specify whether he wishes to "terminate" or "keep running". This is a safety device to prevent accidental early termination. One then specifies whether PEPSUB plotted output is to be obtained immediately ("now") or at some other time ("later"). If "now" is specified, control is given to the FORTRAN plot package which outputs PEPSUB plots, and the documentation associated with PEPSUB (Appendix B) describes the operation in detail. The version of the FORTRAN package employed is the 1000 point modification described in Appendix B.VI. When more than one curve is plotted on the same graph, the overlays are not all plotted at once but must be requested sequentially. By blindly answering "YES" to all questions posed by the FORTRAN package, all plotted output will be obtained correctly. If "later" is given as the time desired for viewing PEPSUB output, the program halts, and the user may then finish his run by entering

BYE
@FIN,C

Do not try to execute PITS more than once between the entering of an @RUN statement and the @FIN statement--only the plot for the last execution within a RUN will be available as output.

If plot is to be obtained prior to 4:00 A.M. the morning following execution of PITS, a run can simply be started, an

@ADD,P PLOT. command given, and the plot will appear. If plot is to be obtained later than 4:00 A.M., the plot file should be saved by entering

@SAVE,S PLOT.

between the BYE and @FIN,C statements above. For details on "later" output of plots, see the discussion in Appendix B concerning use of BASIC-PEP.

It was mentioned earlier that a method exists for obtaining hard copy of all interactions between a PEP run and the program. This employs a program called BFNLIST which is a system level coding available on the 1110 computer. A procedure which works (but is awkward) will be outlined here. Note that if BFN is used, use of hard copy PRINTED output is redundant. Hard copy PLOTTED output must still be obtained in the usual way.

The proper runstream is:

@RUN AS,2231, 1893602639,\$10.00,100
(substitute user i.d. and project number)

(password input)

@CAT,P JPW*PRINTER.
@@TTY BFN=JPW*PRINTER,RCD=IO
@LIB*BACKUP.BASIC CHEMISTRY*WALTERS.
OLD:PITS

Run program PITS. At end of run, specify plot is to be obtained "later". This is critical!

```

BYE
@TTY BFN=OFF
@ASG,UP MYPRINT.
@BRKPT PRINTS/MYPRINT
@BFNLIST,IO JPW*PRINTER.,,90
@BRKPT PRINTS
@FREE MYPRINT.
@SYM MYPRINT.,,PR21
@ADD,P PLOT.

```

Obtain plot--this may also be done on a different run if desired.

```
@FIN,C
```

The sequence above should not be altered without consulting someone familiar with the operation of BFN (Mike Dorl, an MACC systems programmer, devised the above schema in part). Be particularly careful to include or exclude periods in file names as shown; some of the processors are quite sensitive to syntax errors. BFN is not a forgiving routine, but it does provide a method for obtaining full interaction details while running at a PEP terminal. Be sure to copy down the run number so that line printer output can be obtained.

If plotted output is not desired, one or more of the plotting subroutines may be deleted. If this is done by simply EDIT DELETing the routines, there will be several GO TO and GOSUB statements in the remainder of the program which will lack places to go. The easiest way to overcome this problem is to EDIT DELETE the undesired parts of the program, and attempt to run it. A list of undefined line numbers will be generated by BASIC. By typing

in RETURN statements for each of the otherwise undefined lines,
it should be possible to run the program.

D. Units

Throughout the program, the units to be used are:

voltage	volts
current	milliamps
time	microseconds
resistance	ohms
capacitance	microfarads
inductance	henries

IV. Program Listing of PITS

Presented below is a complete listing of program PITS. In addition, Table D.2 gives a general map of which statements execute what sorts of operations.

PITS-1

```

1  C *****
2  C *
3  C * PROGRAM PITS (PROGRAMMED INDEPENDENTLY TIMED SPARK SOURCE) *
4  C * PROGRAM TO CALCULATE CAPACITOR VOLTAGE IN A SPARK SOURCE *
5  C * CONSISTING OF A VARIABLE MUTUALINDUCTANCE STEP-UP TRANSFORMER, *
6  C * CHARGING RESISTOR, FULL WAVE RECTIFIER, CAPACITOR, AND DISCHARGE *
7  C * CIRCUIT. *
8  C *
9  C * WRITTEN BY ALEXANDER SCHEELINE UNDER THE DIRECTION OF: *
10 C * PROFESSOR JOHN P. WALTERS *
11 C * DEPARTMENT OF CHEMISTRY *
12 C * UNIVERSITY OF WISCONSIN *
13 C * MADISON, WISCONSIN 53706 *
14 C *
15 C *****
16 C *****
17 C *
18 C * PRELIMINARY SETUP
19 C *
20 C *****
21 REM PROGRAM PITS (PROGRAMMED INDEPENDENTLY TIMED SPARK SOURCE)
22 REM WRITTEN BY A. SCHEELINE UNDER THE SUPERVISION OF:
23 REM PROF. J.F. WALTERS
24 REM DEPARTMENT OF CHEMISTRY
25 REM UNIVERSITY OF WISCONSIN
26 REM MADISON, WISCONSIN 53706
27 REM VERSION OF JUNE 18, 1977
28 10 DIM F(3),X(1000),Y(1000),I(4,250),E(4,250),T(4,250)
29 20 DIM S(4,25),R(4,9),B(10),U(4,25)
30 30 VAR=ZERO
31 40 DATA 'R(FORWARD BIASED)=','R(REVERSE BIASED)='
32 45 DATA 'L(HENRIES)=','C(MICROFARAD)='
33 50 DATA 'PEAK XFR VOLTAGE=','LENGTH OF DISCHARGE(MICROSECONDS)='
34 55 DATA 'TO(START TIME FROM ZERO CROSSING)=','IO(MILLIAMPS)=','EO='
35 60 DATA 'MAXIMUM PREDICTED BREAKS PER HALF CYCLE='
36 70 MAT READ B
37 75 PRINT 'DO YOU WANT HARD COPY?'
38 80 INPUT A$
39 85 IF A$='YES' OR A$='Y' OR A$='-2' THEN F(1)=1 ELSE F(1)=0
40 90 IF F(1)=1 THEN OPEN FOR SYMBOLIC PRINT:7
41 100 PRINT 'WHAT IS POWER SUPPLY FREQUENCY--'
42 105 PRINT '60 OR 0.1 HERTZ?'
43 110 INPUT IS
44 115 I4=6.283185
45 120 IF IS=60 OR IS=.1 THEN 125 ELSE 100
46 125 IS=I4*IS
47 130 IF F(1)=1 THEN PRINT ON 7 IN IMAGE 'THIS RUN: XX.X HERTZ':IS/14
48 135 GOSUB 11950
49 138 IF F(1)=1 THEN PRINT ON 7 IN FORM '~~~~':
50 140 V1=7
51 145 U9=1
52 150 GOSUB 2025
53 155 GO TO 1000

```

PITS-2

```

54 C *****
55 C *
56 C * FUNCTIONS
57 C *
58 C * THE FOLLOWING CONSTITUTE ALGORITHMS USED IN EVALUATING
59 C * THE CHARGING VOLTAGE AND CURRENT. EACH FUNCTION WORKS ON
60 C * ONE CONCEPTUAL UNIT OF THE CALCULATIONS.
61 C *
62 C *****
63 C *****
64 C *
65 C * FNP
66 C *
67 C * CALCULATE CONSTANTS WHICH ARE FUNCTIONS ONLY OF R,L,C, AND
68 C * PEAK TRANSFORMER VOLTAGE. THESE ARE:
69 C *
70 C * S SQUARED
71 C * S
72 C * Z0
73 C * GAMMA
74 C * VP/Z0
75 C * S-R
76 C *
77 C *****
78 500 DEF FNP(R,L,C)
79 505 IF C>0 THEN S1=R*R-4*L/(C*1E-6) ELSE S1=R*R
80 515 S2=SQR(ABS(S1))
81 520 IF C>0 THEN S3=SQR(R*R+(15*L-1/(15*C*1E-6))**2)
82 525 IF C=0 THEN S3=SQR(R*R+(15*L)**2)
83 530 IF C<0 THEN S4=ATN(((15*L-1/(15*C*1E-6))/R) ELSE S4=ATN(15*L/R)
84 535 S5=E1/S3
85 538 S6=(S2-R)/R
86 540 IF ABS(S6)>1E-3 THEN S6=S2-R ELSE S43
87 542 GO TO 545
88 543 IF C<0 THEN S6=4*L/(R*R*C*1E-6) ELSE S6=0
89 544 S6=-S6*(.5+S6/8)*R
90 545 FNPEND
91 C *****
92 C *
93 C * FNT
94 C *
95 C * CALCULATES
96 C * THETA NOUGHT PLUS GAMMA
97 C * COEFFICIENTS OF COMPLEX HYPERBOLIC FUNCTIONS WHICH ARE
98 C * INDEPENDENT OF THETA.
99 C *
100 C *****
101 550 DEF FNT(T,I,E,R,L,C)
102 555 IF IS>1 THEN T1=IS*(4166.67-T)*1E-6 ELSE T1=IS*T*1E-6
103 560 T2=S4+T1
104 565 REM A8, A9 ARE GLOBAL--WATCH IT!
105 570 A8=COS(T2)
106 575 A9=SIN(T2)
107 580 T3=SS*(2*IS*L*A8-R*A9)-IS*(2*L*(1+.001+E*R*C*1E-6)
108 585 T4=E*IS*C*1E-6*SS*A9
109 590 IF C>0 THEN S9S ELSE 605
110 595 T5=SS*(R*A8-2*A9/(15*C*1E-6))- (I*R*.001+2*E)

```

PITS-3

```

111 400 GO TO 410
112 405 T5=SS*R*AB-I*R*.001
113 410 T6=I*.001-SS*AB
114 415 FNEED
115 C *****
116 C *
117 C * FNS
118 C *
119 C * CALCULATES CSINH
120 C *
121 C *****
122 450 DEF FNS(A)
123 455 IF S1>0 THEN 480 ELSE IF S1=0 THEN 470
124 460 FNS=SIN(S2*A)/S2
125 465 GO TO 485
126 470 FNS=A
127 475 GO TO 485
128 480 FNS=(EXP(A*S2)-EXP(-A*S2))/(2*S2)
129 485 FNEED
130 C *****
131 C *
132 C * FNC
133 C *
134 C * CALCULATES CCOSH
135 C *
136 C *****
137 700 DEF FNC(A)
138 705 IF S1>0 THEN 730 ELSE IF S1=0 THEN 720
139 710 FNC=COS(S2*A)
140 715 GO TO 735
141 720 FNC=1
142 725 GO TO 735
143 730 FNC=(EXP(A*S2)+EXP(-A*S2))/2
144 735 FNEED
145 C *****
146 C *
147 C * FNI
148 C *
149 C * CALCULATES CHARGING CURRENT IN MILLIAMPS.
150 C *
151 C *****
152 750 DEF FNI(T,R)
153 755 A7=T*SE-7/L1
154 758 IF A7*S2>10 THEN IF S1>0 THEN 770
155 760 A8=FNC(A7)
156 765 A9=FNS(A7)
157 770 A6=SS*COS(I5*T*1E-6-T2)
158 773 IF A7*S2>10 THEN IF S1>0 THEN 778
159 775 FNI=(A6+EXP(-R*A7))*(A9*T5+AB*I6)*1000
160 776 GO TO 780
161 778 FNI=(A6+EXP(S6*A7))*(T5/S2+T6)*.5)*1000
162 780 FNEED
163 C *****
164 C *
165 C * FNE
166 C *
167 C * CALCULATES CAPACITOR VOLTAGE.

```

PITS-4

```

168 C *
169 C *****
170 800 DEF FNE(T,R,C)
171 805 A7=T*SE-7/L1
172 808 IF A7*82-10 THEN IF S1>0 THEN 820
173 810 A8=FNC(A7)
174 815 A9=FNS(A7)
175 820 A4=SS*SIN(I5*T*1E-4-T2)
176 823 IF A7*82-10 THEN IF S1=0 THEN 828
177 825 FNE=A4-EXP(-R*A7)*(A9*T3-AB*T4)
178 826 GO TO 830
179 828 FNE=A4-EXP(S4*A7)*(T3/S2-T4)*.5
180 830 IF C=0 THEN A7=1/(I5+C*1E-6) ELSE A7=0
181 835 FNE=A7*FNE
182 840 FNE=0
183 C *****
184 C *
185 C * SUBROUTINE TO SET DIODE BIAS CONDITION AND CALCULATE CONSTANTS.
186 C *
187 C *****
188 850 Q1=1
189 855 REM Q1=1-FORWARD BIAS; Q1=0-REVERSE BIAS
190 860 CALL FNP(R1,L1,C1)
191 862 REM AT BREAK TIME,EXCHANGE C1 WITH A SCRATCH REGISTER
192 863 REM BEFORE CALLING THIS ROUTINE.
193 865 CALL FNT(T,I2,E4,R1,L1,C1)
194 868 REM T=MOST RECENTLY COMPUTED TIME. ETC.
195 870 RETURN
196 875 Q1=0
197 885 R1=R2
198 890 GOSUB 860
199 895 R1=R2
200 900 RETURN
201 C *****
202 C *
203 C * FNL
204 C *
205 C * INTERPOLATION ROUTINE.
206 C *
207 C * GIVEN CURVES Y AND Z WITH VALUES Y1 AND Z1 AT X=X1,
208 C * AND Y2 AND Z2 FOR VALUES AT X=X2, FIND X (=FNL) WHEN Y=Z.
209 C *
210 C *****
211 950 DEF FNL(X1,Y1,Z1,X2,Y2,Z2)
212 955 IF Y2-Z2+Y1=0 THEN 970
213 960 FNL=(X2*(Z1-Y1)+X1*(Y2-Z2))/(Y2-Z2+Y1)
214 965 GO TO 975
215 970 FNL=(X1+X2)/2
216 975 FNE=0

```

PITS-5

```

217 C *****
218 C *
219 C * CORE ROUTINE
220 C *
221 C * THIS ROUTINE HAS NO DEFAULTS.
222 C * QUESTION IS SELF-DOCUMENTING.
223 C *
224 C *****
225 1000 REM MAIN CONTROL ROUTINE
226 1003 PRINT ' '
227 1005 PRINT 'THE POSSIBLE ROUTINES ARE:'
228 1010 PRINT 'INPUT, CALCULATE, OUTPUT, TERMINATE.'
229 1015 PRINT 'ENTER A NUMBER 1, 2, 3, OR 4.'
230 1020 INPUT V1
231 1023 PRINT ' '
232 1025 IF V1<>INT(V1) OR V1<1 OR V1>4 THEN 1015
233 1030 ON V1 GO TO 1035,1045,1055,1070
234 1035 GOSUB 2005
235 1040 GO TO 1060
236 1045 GOSUB 4000
237 1050 GO TO 1060
238 1055 GOSUB 8000
239 1060 PRINT ' '
240 1065 GO TO 1005
241 1070 GOSUB 12000
242 1075 GO TO 1060

```


PITG-6

```

243 C *****
244 C *
245 C * INITIALIZATION ROUTINE
246 C *
247 C * OPTIONS ARE:
248 C * 1) ENTER R,L,C, AND REVERSE BIAS R ONLY.
249 C * 2) ENTER INITIAL CONDITIONS.
250 C * 3) 1) AND 2).
251 C * 4) ENTER BREAK TIMES AND/OR VOLTAGES; ALSO MAXIMUM
252 C * PREDICTED BREAKS PER HALF CYCLE.
253 C * 5) 1) AND 4).
254 C * 6) 2) AND 4).
255 C * 7) 1), 2), AND 4).
256 C *
257 C * DEFAULTS: -1 USE PREVIOUSLY ENTERED VALUE.
258 C * -2 USE STANDARD DEFAULT VALUE.
259 C *
260 C * STANDARD DEFAULTS:
261 C *
262 C * FORWARD RESISTANCE (OHMS) 40000
263 C * REVERSE RESISTANCE (OHMS) 33E6
264 C * INDUCTANCE (HENRIES) 25
265 C * CAPACITANCE (MICROFARADS) 0.01
266 C * PEAK TRANSFORMER VOLTAGE 10000
267 C * DISCHARGE DURATION (MICROSECONDS) 50
268 C * INITIAL TIME VS ZERO CROSSING (US) 0
269 C * INITIAL CURRENT (MILLIAMPS) 0
270 C * INITIAL CAPACITOR VOLTAGE (VOLTS) 0
271 C * MAX. PREDICTED BREAKS PER HALF CYCLE 25
272 C *
273 C * BREAK TIMES MULTIPLES OF 1000 US
274 C * BREAK VOLTAGES 4000
275 C *
276 C * USE OF EDITING FEATURES FOR TIME AND VOLTAGE INPUT IS
277 C * EXPLAINED IN DOCUMENTATION.
278 C *
279 C *****
280 2000 REM INITIALIZATION ROUTINE
281 2005 PRINT "WHAT INITIALIZATION OPTION DO YOU DESIRE?";
282 2010 INPUT V1
283 2015 IF V1=-2 THEN V1=7
284 2020 IF V1<INT(V1) OR V1<1 OR V1>7 THEN 2005
285 2025 V9=0
286 2030 FOR J1=1 TO 10
287 2035 IF 1<=J1 AND J1<=4 THEN IF MOD(V1,2)=1 THEN 2050 ELSE 2105
288 2040 IF 5<=J1 AND J1<=9 THEN IF V1<1 AND V1<=4 AND V1<0 THEN 2050 ELSE 2185
289 2045 IF J1=9 AND V1<3 THEN 2050 ELSE 2185
290 2050 PRINT B$(J1);
291 2055 INPUT V2
292 2060 IF V2=-1 AND V9=1 THEN V2=-2
293 2065 ON J1 GOTO 2070,2090,2100,2110,2120,2130,2140,2155,2165,2175
294 2070 IF V2=-2 THEN R1=40000 ELSE IF V2<0 THEN R1=V2
295 2075 IF V2<0 AND V2<-1 AND V2<-2 THEN 2080 ELSE 2185
296 2080 PRINT B$(J1); "V2;" IS NOT ALLOWED."
297 2085 GO TO 2050
298 2090 IF V2=-2 THEN R2=33E6 ELSE IF V2>0 THEN R2=V2
299 2095 GO TO 2075

```

PITS-7

```

300 2100 IF V2=-2 THEN L1=25 ELSE IF V2>0 THEN L1=V2
301 2105 GO TO 2075
302 2110 IF V2=-2 THEN C1=.01 ELSE IF V2=0 THEN C1=V2
303 2115 IF V2<0 AND V2>=-1 AND V2<=-2 THEN 2080 ELSE 2185
304 2120 IF V2=-2 THEN E1=E2=10000 ELSE IF V2>0 THEN E1=E2=V2
305 2125 GO TO 2075
306 2130 IF V2=-2 THEN T8= 50 ELSE IF V2>0 THEN T8=V2
307 2135 GO TO 2115
308 2140 IF V2=-2 THEN T7=0 ELSE IF V2>0 THEN T7=V2
309 2145 IF T7>8333. THEN 2080
310 2150 GO TO 2115
311 2155 IF V2=-2 THEN I1=0 ELSE IF V2<>-1 THEN I1=V2
312 2160 GO TO 2185
313 2165 IF V2=-2 THEN E5=0 ELSE IF V2<>-1 THEN E5=V2
314 2170 GO TO 2185
315 2175 IF V2=-2 THEN I6=25 ELSE IF V2>0 THEN I6=V2
316 2180 IF V2>25 THEN 2080 ELSE 2075
317 2185 NEXT J1
318 2190 G1=0
319 2195 IF V1<4 THEN RETURN
320 2200 'FOR HOW MANY HALF-CYCLES DO YOU WISH TO ENTER BREAK TIMES?'
321 2205 INPUT V1
322 2210 PRINT ' '
323 2215 IF INT(V1)<>V1 OR V1<-2 OR V1>4 THEN 2200
324 2220 IF V1=-1 OR V1=0 THEN 2240
325 2225 IF V1=-2 THEN 2230 ELSE 2255
326 2230 FOR J2=1 TO 4
327 2235 FOR J1=1 TO 8 S(J2,J1)=J1*1000
328 2240 S(J2,9)=0
329 2245 NEXT J2
330 2250 RETURN
331 2255 PRINT 'ENTER BREAK TIMES IN MICROSECONDS FOR EACH HALF CYCLE.'
332 2260 PRINT 'AFTER ALL BREAKS ENTERED FOR A HALF CYCLE, INPUT 0.'
333 2265 FOR J2=1 TO V1
334 2270 PRINT ' '
335 2275 PRINT 'HALF CYCLE' J2
336 2280 PRINT ' '
337 2285 PRINT 'ENTER BREAK TIMES AFRESH OR ADD TO PREVIOUS LIST'
338 2290 PRINT 'TYPE "FRESH" OR "ADD TO"'
339 2295 INPUT A$
340 2300 IF A$=-2 OR A$='FRESH' THEN 2310 ELSE 2330
341 2310 R(J2,2)=0
342 2315 GO TO 2335
343 2320 GOSUB 3095
344 2325 A4=R(J2,2)
345 2330 PRINT ' '
346 2335 PRINT 'BREAK TIME='
347 2340 INPUT A3
348 2345 IF A4=25 AND A3<>-1 AND A3>0 THEN 2500
349 2350 IF A3=-2 THEN A3=1000*(R(J2,2)+1)
350 2355 IF A3=-1 OR A3=0 THEN 2400
351 2360 IF A3<0 OR A3>8333.3 THEN 2365 ELSE 2380
352 2365 PRINT 'BREAK TIME OF 'A3' IS NOT ALLOWED.'
353 2370 PRINT 'TIME MUST BE BETWEEN 0 AND 8333.3.'
354 2375 GO TO 2335
355 2380 R(J2,2)=R(J2,2)+1
356 2385 A4=R(J2,2)

```

FITS-8

```

357 2390 S(J2,A4)=A3
358 2395 GO TO 2335
359 2400 S(J2,A4+1)=0
360 2405 GOSUB 2540
361 2410 PRINT 'DO YOU WISH TO EDIT BREAK TIMES?'
362 2415 INPUT A5
363 2420 IF A5='YES' OR A5='Y' OR A5='-2' THEN 2430
364 2425 IF A5='NO' OR A5='N' OR A5='0' OR A5='-1' THEN 2530 ELSE 2410
365 2430 GOSUB 11950
366 2435 PRINT 'BREAK TIMES ARE:'
367 2440 FOR J3=1 TO A4 PRINT J3,S(J2,J3)
368 2445 PRINT 'REMOVE WHICH BREAK?'
369 2450 INPUT V5
370 2455 IF V5<=0 THEN 2475
371 2460 IF V5<>INT(V5) OR V5>A4 THEN 2445
372 2465 S(J2,V5)=0
373 2470 GO TO 2445
374 2475 GOSUB 2540
375 2480 PRINT 'SATISFIED FOR THIS HALF CYCLE?'
376 2485 INPUT A5
377 2490 IF A5='YES' OR A5='Y' OR A5='-2' OR A5='-1' OR A5='0' THEN 2530
378 2495 IF A5='NO' OR A5='N' THEN 2335 ELSE 2480
379 2500 GOSUB 2540
380 2505 IF A4=25 THEN 2510 ELSE 2350
381 2510 PRINT 'LAST INPUT IGNORED--YOU ALREADY HAVE 25 BREAKS IN THIS'
382 2515 PRINT ' HALF CYCLE.'
383 2520 PRINT 'EITHER EDIT BREAK TIMES OR GO TO THE NEXT HALF CYCLE.'
384 2525 GO TO 2410
385 2530 NEXT J2
386 2535 GO TO 2640
387 2540 A5=A4-1
388 2545 IF A5<=0 THEN RETURN
389 2550 FOR J3=1 TO A5
390 2555 A6=A5-J3+1
391 2560 FOR J4=1 TO A6
392 2565 IF S(J2,J4)>S(J2,J4+1) THEN S(J2,J4)=S(J2,J4+1)
393 2570 NEXT J4
394 2575 NEXT J3
395 2580 FOR J3=1 TO A5
396 2585 IF S(J2,J3)=S(J2,J3+1) OR S(J2,J3)=0 THEN 2590 ELSE 2600
397 2590 FOR J4=J3 TO A5 S(J2,J4)=S(J2,J4+1)
398 2595 S(J2,A4)=0
399 2600 NEXT J3
400 2605 A5=A5-1
401 2610 FOR J4=1 TO A4
402 2615 IF S(J2,J4)>0 THEN A5=A5+1
403 2620 NEXT J4
404 2625 A4=A5+1
405 2630 R(J2,2)=A4
406 2635 RETURN
407 2640 FOR V1=1 TO 2 PRINT ' '
408 2645 PRINT 'ENTER BREAK VOLTAGES FOR HOW MANY HALF-CYCLES?'
409 2650 INPUT V1
410 2655 PRINT ' '
411 2660 IF INT(V1)<>V1 OR V1<=-2 OR V1>4 THEN 2640
412 2665 IF V1=-1 OR V1=0 THEN RETURN
413 2670 IF V1=-2 THEN 2675 ELSE 2700

```

PITS-9

```

414 2675 FOR J2=1 TO 4
415 2680 FOR J7=1 TO 7 U(J2,J7)=6000
416 2685 U(J2,8)=0
417 2690 NEXT J7
418 2695 RETURN
419 2700 PRINT 'ENTER BREAK VOLTAGES IN VOLTS IN THE ORDER DESIRED.'
420 2705 PRINT 'DEFAULT -2 GIVES 6000 VOLTS.'
421 2710 PRINT 'IN FRESH MODE, AFTER LAST BREAK, ENTER ZERO.'
422 2715 PRINT ' '
423 2720 FOR J2=1 TO V1
424 2725 PRINT ' '
425 2730 PRINT 'HALF-CYCLE':J2
426 2735 PRINT ' '
427 2740 PRINT 'FRESH OR EDIT':
428 2745 INPUT A$
429 2750 IF A$='FRESH' OR A$='-2' THEN 2760 ELSE 2755
430 2755 IF A$='EDIT' THEN 2770 ELSE 2725
431 2760 A4=0
432 2765 GO TO 2960
433 2770 GOSUB 3130
434 2775 PRINT 'FRESH, INSERT, DELETE, LIST, OR DONE':
435 2780 INPUT A$
436 2785 IF A$='DONE' THEN 3035
437 2790 IF A$='FRESH' THEN 2760
438 2795 IF A$='INSERT' THEN 2900
439 2800 IF A$='DELETE' THEN 2865
440 2805 IF A$='LIST' THEN 2775
441 2810 GOSUB 11950
442 2815 IF A4=0 THEN 2855
443 2820 PRINT 'NUMBER':TAB(10):'BREAK VOLTAGE'
444 2825 PRINT ' '
445 2830 FOR J7=1 TO A4
446 2835 PRINT IN FORM 'XX 12PSX':J7,U(J2,J7)
447 2840 NEXT J7
448 2845 PRINT ' '
449 2850 GO TO 2775
450 2855 PRINT 'NO DATA IN ARRAY FOR THIS HALF-CYCLE.'
451 2860 GO TO 2845
452 2865 PRINT 'WHICH BREAK':
453 2870 INPUT J3
454 2875 IF INT(J3)<>J3 OR J3>A4 OR J3<1 THEN 2865
455 2880 FOR J4=J3 TO A4 LET U(J2,J4)=U(J2,J4+1)
456 2885 U(J2,A4)=0
457 2890 A4=A4-1
458 2895 GO TO 2845
459 2900 IF A4=25 THEN 2905 ELSE 2915
460 2905 PRINT 'ALREADY 25 BREAKS IN HALF-CYCLE. ALL FULL.'
461 2910 GO TO 2845
462 2915 PRINT 'INSERT AFTER WHICH BREAK':
463 2920 INPUT J3
464 2925 IF INT(J3)<>J3 OR J3>A4 OR J3>24 OR J3<0 THEN 2915
465 2930 IF J3=A4 THEN 2935 ELSE 2945
466 2935 GOSUB 3045
467 2940 GO TO 2045
468 2945 FOR J4=A4 TO J3+1 STEP -1 LET U(J2,J4+1)=U(J2,J4)
469 2950 GOSUB 3045
470 2955 GO TO 2845

```

PITS-10

```

471 2940 J3=1
472 2945 PRINT 'BREAK VOLTAGE='
473 2970 INPUT V2
474 2975 IF V2=0 THEN 2845
475 2980 IF V2=-2 THEN V2=6000
476 2985 IF V2<0 THEN 2990 ELSE 3000
477 2990 PRINT 'ILLEGAL VOLTAGE'
478 2995 GO TO 2965
479 3000 U(J2,J3)=V2
480 3005 A4=A4+1
481 3010 IF A4>25 THEN U(J2,J3+1)=0
482 3015 J3=J3+1
483 3020 IF A4=25 THEN 3025 ELSE 2965
484 3025 PRINT '25 BREAKS. TIME TO EDIT.'
485 3030 GO TO 2845
486 3035 NEXT J2
487 3040 RETURN
488 3045 PRINT 'BREAK VOLTAGE='
489 3050 INPUT V2
490 3055 IF V2=-2 THEN V2=6000
491 3060 IF V2<0 THEN 3065 ELSE 3075
492 3065 PRINT 'ILLEGAL VOLTAGE'
493 3070 GO TO 3045
494 3075 U(J2,J3+1)=V2
495 3080 A4=A4+1
496 3085 U(J2,A4+1)=0
497 3090 RETURN
498 3095 FOR J7=1 TO 25
499 3100 IF S(J2,J7)=0 THEN 3105 ELSE 3115
500 3105 R(J2,2)=J7-1
501 3110 RETURN
502 3115 NEXT J7
503 3120 R(J2,2)=25
504 3125 RETURN
505 3130 FOR J7=1 TO 25
506 3135 IF U(J2,J7)=0 THEN 3140 ELSE 3150
507 3140 A4=J7-1
508 3145 RETURN
509 3150 NEXT J7
510 3155 A4=25
511 3160 RETURN

```

FICS-11

```

512 C *****
513 C *
514 C * CALCULATION CONTROL ROUTINE
515 C *
516 C * CHOOSE THRESHOLDING METHOD. NO DEFAULT.
517 C * 'ABORT' CANCELS SUBROUTINE CALL.
518 C *
519 C *****
520 4000 REM CALCULATION CONTROL ROUTINE
521 4005 PRINT
522 4010 PRINT 'CHOOSE CALCULATION METHOD: 1) TIME THRESHOLDING'
523 4015 PRINT TAB(27);'2) VOLTAGE THRESHOLDING'
524 4020 REM LINE FOR AUTO MODE SELECTION PROMPT
525 4025 PRINT TAB(27);'3) ABORT'
526 4035 PRINT 'CHOOSE 1, 2, OR 3'
527 4040 INPUT D1
528 4045 REM D1-D9 ARE LOCAL SCRATCH VARIABLES.
529 4050 IF D1=3 THEN RETURN
530 4055 IF D1<>INT(D1) OR D1<1 OR D1>2 THEN 4035
531 4060 GOSUB 14000
532 4065 GOSUB 14030
533 4070 ON D1 GO TO 4075, 4085
534 4075 GOSUB 6000
535 4080 RETURN
536 4085 GOSUB 16000
537 4090 RETURN

```

PITS-12

```

538 C *****
539 C *
540 C * VOLTAGE THRESHOLD MANIFOLD CALCULATIONS.
541 C *
542 C *****
543 C *****
544 C *
545 C * FNR
546 C *
547 C * FUNCTION TO SELECT VALUE OF VOLTAGE MANIFOLD AT TIME T.
548 C * CALLS OTHER FUNCTIONS U,V,W,X,Y, AND /WK Z FOR ACTUAL
549 C * EVALUATIONS.
550 C *
551 C *****
552 4300 DEF FNR(T)
553 4305 ON D2 GO TO 4310,4320,4330,4340,4350,4360
554 4310 FNR=FNU(T)
555 4315 GO TO 4365
556 4320 FNR=FNV(T)
557 4325 GO TO 4365
558 4330 FNR=FNU(T)
559 4335 GO TO 4365
560 4340 FNR=FNX(T)
561 4345 GO TO 4365
562 4350 FNR=FNW(T)
563 4355 GO TO 4365
564 4360 FNR=FNZ(T)
565 4365 FNR=FNR
566 C *****
567 C *
568 C * FNU TYPED IN INITIALIZATION VOLTAGES = MANIFOLD
569 C *
570 C *****
571 5000 DEF FNU(T)
572 5005 FNU=U(V1,G3)
573 5010 FNR=FNR
574 C *****
575 C *
576 C * FNV EQUIVALENT PATTERN MANIFOLD
577 C *
578 C *****
579 5020 DEF FNV(T)
580 5025 FNV=D3
581 5030 FNR=FNR
582 C *****
583 C *
584 C * FNV RANDOM PATTERN MANIFOLD
585 C *
586 C *****
587 5040 DEF FNV(T)
588 5045 IF G3=D4 THEN 5050 ELSE 5060
589 5050 D5=D3*RND
590 5055 D4=D3
591 5060 FNV=D5
592 5065 FNR=FNR
593 C *****
594 C *

```

2ITS-13

```

595 C * FNK SINE PATTERN MANIFOLD
596 C *
597 C *****
598 5080 DEF FNK(T)
599 5085 FNK=D3*ABS(SIN(15*T+1E-6+D4))
600 5090 FNEED
601 C *****
602 C *
603 C * FNY RAMP PATTERN MANIFOLD
604 C *
605 C *****
606 5100 DEF FNY(T)
607 5105 FNY=D4*T+D3
608 5110 FNEED
609 C *****
610 C *
611 C * FNZ USER DEFINABLE MANIFOLD; NOW SET UP AS TRAPAZOIDAL PATTERN.
612 C *
613 C *****
614 5150 REM USER DEFINED ROUTINE MAY RUN 5151-5200
615 5151 DEF FNZ(T)
616 5155 IF T>D3 THEN IF T<(8333.33-D4) THEN 5170 ELSE 5180
617 5160 FNZ=(D5/D3)*T
618 5165 GO TO 5185
619 5170 FNZ=(D5/D4)*(8333.33-T)
620 5175 GO TO 5185
621 5180 FNZ=D5
622 5185 FNEED

```


PI25-14

```

423 C *****
424 C *
425 C * TIME THRESHOLDING ROUTINE
426 C *
427 C * CHOICES FOR SOURCE OF TIMES:
428 C * 'THIS' -USES TIMES TYPED IN DURING INITIALIZATION OR
429 C * 'THIS' -PLACED IN THIS HALF-CYCLE DURING A PREVIOUS
430 C * CALCULATION.
431 C *
432 C * 'PREVIOUS'-IF HALF-CYCLE 'N' WAS SPECIFIED, THE TIMES
433 C * CALCULATED FOR HALF-CYCLE N-1 ARE EMPLOYED FOR
434 C * FOR THE PRESENT HALF-CYCLE'S CALCULATIONS AS WELL.
435 C *
436 C * FOR HALF CYCLE 1, 'PREVIOUS HALF-CYCLE' IS NUMBER 4.
437 C *
438 C * DEFAULT='THIS'='-2'
439 C * ZERO BREAKS, SIGNIFIED BY TYPING IN BREAK TIME =0 IN
440 C * INITIALIZATION, IS A LEGITIMATE PATTERN.
441 C *
442 C *****
443 C 6000 REM TIME THRESHOLDING ROUTINE
444 C 6001 PRINT ' '
445 C 6003 GO TO 6070
446 C 6005 T=T+50
447 C 6010 IF T<S(V1,G3) AND S(V1,G3)>0 OR S(V1,G3)=0 THEN 6015 ELSE 6025
448 C 6015 GOSUB 14335
449 C 6018 IF A1=250 THEN IF A9<=1 THEN 6045
450 C 6020 IF A9>1 THEN 6005 ELSE RETURN
451 C 6025 IF G3=25 THEN 6040
452 C 6030 GOSUB 14465
453 C 6035 GO TO 6018
454 C 6040 'OVER 25 BREAKS ATTEMPTED.'
455 C 6045 PRINT 'CALCULATIONS HALTED AFTER 'A1' POINTS.'
456 C 6050 PRINT 'ATTEMPTING TO OUTPUT THESE DATA MAY CRASH PROGRAM. '
457 C 6055 PRINT 'TRY FRESH COMPUTATION.'
458 C 6060 RETURN
459 C 6070 PRINT 'USE TIMES FROM THIS HALF-CYCLE OR PREVIOUS HALF-CYCLE.'
460 C 6075 PRINT 'INPUT 'THIS' OR 'PREVIOUS''
461 C 6080 INPUT A4
462 C 6090 IF A4='THIS' OR A4='-2' THEN 6005
463 C 6095 IF A4<>'PREVIOUS' THEN 6075
464 C 6100 IF V1=1 THEN G4=4 ELSE G4=V1-1
465 C 6105 FOR G5=1 TO 25 LET S(V1,G5)=S(G4,G5)
466 C 6110 GO TO 6005

```

PIIS-15

```

467 C *****
468 C *
469 C * OUTPUT ROUTINE
470 C *
471 C * OPTIONS:
472 C * 1) FULL PRINT OF CHARGING CURVE AND PARAMETER DUMP.
473 C * 2) PRINT OPEN VOLTAGE AND PARAMETER DUMP.
474 C * 3) PARAMETER DUMP ONLY.
475 C * 10) MINIPLOT ONLY.
476 C * 20) PEPGUD ONLY.
477 C * 30) BOTH PLOTS.
478 C * 11) 1) + 10)
479 C * 12) 2) + 10)
480 C *
481 C *
482 C *
483 C * 33) 3) + 30)
484 C *
485 C * DEFAULT (-2) IS OPTION 33-FULL PLOT AND MINIMUM PRINT.
486 C *
487 C * SCALING OPTIONS:
488 C *
489 C * -2 500 MA AND 15 KV FULL SCALE
490 C * 1 MAXIMUM DATUM=FULL SCALE
491 C * 2 FULL SCALE = PEAK TRANSFORMER VOLTAGE
492 C * 3 USER SET FULL SCALE
493 C *
494 C *****
495 8000 REM OUTPUT CONTROL ROUTINE
496 8002 IF R(1,3)=0 THEN 8003 ELSE 8005
497 8003 PRINT 'HALF-CYCLE 1 HAS NO DATA. OUTPUT FORBIDDEN.'
498 8004 RETURN
499 8005 PRINT '
700 8010 PRINT 'WHAT OUTPUT OPTION DO YOU WANT?'
701 8020 INPUT V
702 8030 IF INT(V)<0 THEN 8010
703 8040 IF V=-2 THEN V=33
704 8050 V2=MOD(V,10)
705 8060 IF V2=0 OR V2=3 OR V2=33 THEN 8010
706 8070 IF V=0 THEN RETURN
707 8080 V=(V-V2)/10
708 8085 REM V2=PRINT OPTION, V=PLOT OPTION.
709 8087 PRINT '
710 8090 PRINT 'HOW MANY HALF CYCLES ARE TO BE OUTPUT?'
711 8100 INPUT V1
712 8105 PRINT '
713 8110 IF V1>INT(V1) OR ABS(V1)<1 OR V1>4 THEN 8090
714 8120 IF V1=-2 THEN V1=1
715 8130 FOR K=1 TO V1
716 8135 IF R(K,3)=1 THEN 8190 ELSE IFR(K,3)=-1 THEN 8155
717 8140 PRINT 'HALF CYCLE 'K' CONTAINS NO INFORMATION.'
718 8145 PRINT 'OUTPUT FEWER HALF CYCLES.'
719 8150 GO TO 8090
720 8155 PRINT 'HALF CYCLE 'K' CONTAINS INFORMATION UNRELATED'
721 8160 PRINT 'TO HALF CYCLE 1. IF THIS IS INTENTIONAL.'
722 8165 PRINT 'ENTER 'YES' OTHERWISE ENTER ANYTHING ELSE.'
723 8170 INPUT V3

```

PITS-16

```

724      8175 IF V4='YES' OR V4='Y' THEN 8190 ELSE 8180
725      8180 PRINT 'RETURNING TO CONTROL ROUTINE.'
726      8185 RETURN
727      8190 NEXT K
728      8193 U7=V1
729      8195 PRINT 'INPUT TITLE. ''-2'' GIVES DEFAULT.'
730      8200 INPUT W2$
731      8203 PRINT ' '
732      8205 IF W2$='-2' THEN 8210 ELSE 8220
733      8210 W2$=STR$(Z1+1)
734      8215 W2$='SPARK PATTERN '+W2$
735      8220 IF V2=0 OR V2=3 AND V4=0 THEN 8240
736      8225 IF V=0 AND V2=3 THEN 8240
737      8230 GOSUB 11005
738      8240 IF V=0 AND V2=0 THEN V2=3
739      8245 IF V=0 AND V2=3 THEN GOSUB 11005
740      8250 IF V=0 THEN RETURN
741      8255 REM PLOT SETUP STARTS HERE.
742      8258 PRINT ' '
743      8260 PRINT 'CHOOSE PLOT VARIABLES.'
744      8262 PRINT 'ANSWER ''YES'' OR '' '
745      8265 PRINT ' ''Y'' FOR EACH PLOTTED VARIABLE DESIRED.'
746      8270 PRINT ' '
747      8275 PRINT TAB(10);'CAPACITOR VOLTAGE';
748      8280 INPUT V1$
749      8285 IF V1$='YES' OR V1$='Y' OR V1$='-2' THEN V3=1 ELSE V3=0
750      8290 PRINT TAB(11);'CHARGING CURRENT';
751      8295 INPUT V1$
752      8300 IF V1$='YES' OR V1$='Y' OR V1$='-2' THEN V4=1 ELSE V4=0
753      8305 PRINT TAB(15);'XHFV VOLTAGE';
754      8310 INPUT V1$
755      8315 IF V1$='YES' OR V1$='Y' THEN V5=1 ELSE V5=0
756      8320 V6=V3+V4+V5
757      8325 IF V6=0 THEN 8360
758      8328 PRINT ' '
759      8330 'ENTER SCALING OPTION';
760      8335 INPUT U7
761      8338 PRINT ' '
762      8340 IF U7<1 OR U7>3 OR U7<>INT(U7) THEN 8345 ELSE 8350
763      8345 IF U7=-2 THEN 8350 ELSE 8330
764      8350 A1=A2=A3=0
765      8355 FOR K=1 TO V1
766      8360 A7=R(K,1)
767      8362 FOR K1=1 TO A7
768      8365 IF E(K,K1)>A1 THEN A1=E(K,K1)
769      8370 IF I(K,K1)>A2 THEN A2=I(K,K1)
770      8375 IF I(K,K1)>A3 THEN A3=I(K,K1)
771      8380 NEXT K1
772      8385 NEXT K
773      8390 IF V3=0 OR V5=1 AND E1>A1 THEN A1=E1
774      8395 IF A3=0 OR V4=0 THEN 8400 ELSE 8410
775      8400 U5=0
776      8405 GO TO 8415
777      8410 IF V4=1 THEN IF V6=1 THEN U5=A3 ELSE U5=(A3/A2)*A1*.5
778      8411 IF V4=0 THEN U5=0
779      8412 REM MUST SET XMIN AND XMAX JUST BEFORE CALLING PEPHUB OR MINIPLOT.
780      8415 REM SET FULL SCALE

```

FITS-17

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781      8420 IF V4=1 AND V6=1 THEN W4=A2 ELSE W4=A1
782      8425 IF V7=-2 AND V4=1 AND V6=1 THEN W3=500
783      8430 IF V7=-2 AND V6=1 OR V7=-2 AND V4<1 THEN W4=15000
784      8435 IF V7=2 THEN W4=E1
785      8440 IF V7=3 THEN 8445 ELSE 8480
786      8445 IF V4=V6 THEN 8458
787      8448 PRINT 'FULL SCALE VOLTAGE=';
788      8453 INPUT W4
789      8455 IF W4=0 THEN 8448
790      8456 IF V4<1 THEN 8465
791      8458 PRINT 'FULL SCALE CURRENT=';
792      8460 INPUT A2
793      8463 IF A2=0 THEN 8458
794      8465 IF V4=V6 THEN A2=A2/2 ELSE W4=A2
795      8470 IF V4<V6 THEN W5=(A2/A2)*W4*.5
796      8475 IF V4<V6 THEN A1=W4
797      8478 PRINT ' '
798      8480 IF W4=1 AND V6=1 THEN W3='MILLIAMPERES' ELSE W3='VOLTS'
799      8485 PRINT 'IF SATISFIED WITH PLOT SETUP, ENTER ''YES'' OR ''Y'' '
800      8490 PRINT 'OTHERWISE, YOU CAN GO BACK AND TRY AGAIN.'
801      8495 PRINT 'ENTERING ''ABORT'' TERMINATES THIS PASS OF OUTPUT.'
802      8500 PRINT 'SATISFIED';
803      8505 INPUT V15
804      8510 IF V15='ABORT' THEN RETURN
805      8515 IF V15='YES' OR V15='Y' OR V15='-2' THEN 8520 ELSE 8240
806      8520 IF V=2 THEN 8490
807      8523 REM SETUP FOR MINI PLOT
808      8525 FOR A=1 TO V1
809      8530 W6=R(K-1)
810      8535 W2=8333.3*A*(K-4)
811      8540 W3=W2-8333.33
812      8545 FOR J=1 TO V4
813      8550 IF J=1 THEN W15='NEW' ELSE W15='OVERLAY'
814      8555 IF J=V6 THEN F(2)=0 ELSE F(2)=1
815      8560 IF J=1 THEN 8565 ELSE 8570
816      8565 FOR J1=1 TO W6 X(J1)=Y(K,J1)+W3
817      8570 IF J=1 THEN IF V3=1 THEN 8620
818      8575 IF V4=1 THEN IF J=2 AND V3=1 OR J=1 THEN 8635
819      8580 REM PLOT HALF CYCLE
820      8585 FOR J1=1 TO 60
821      8590 X(J1)=J1*138.8889+W3
822      8595 IF J=1 THEN Y(J1)=E1*SIN((15*J1+1.3888889E-4) ELSE Y(J1)=E1
823      8600 NEXT J1
824      8605 W6=60
825      8610 W1=40
826      8615 GO TO 8465
827      8620 W1=10
828      8625 FOR J1=1 TO W6 Y(J1)=E(K,J1)
829      8630 GO TO 8465
830      8635 W1=14
831      8640 IF V4=1 AND V6=1 THEN 8640
832      8645 V8=W4/A2*.5
833      8650 FOR J1=1 TO W6 Y(J1)=I(K,J1)*V8
834      8655 GO TO 8465
835      8660 FOR J1=1 TO W6 Y(J1)=I(K,J1)
836      8665 GOSUB 10000
837      8670 NEXT J

```

PITS-18

```

838      8475 NEXT K
839      8480 REM PEPUR CALLING SEQUENCE
840      8485 IF V.1 THEN 8486 ELSE 8915
841      8484 PRINT 'PROCEED WITH PEPUR';
842      8487 INPUT V19
843      8488 IF V19='YES' OR V19='Y' OR V19='-2' THEN 8490 ELSE 8915
844      8490 W6=0
845      8495 FOR K=1 TO V1 W6=W6+R(K,1)
846      8700 U7=U3+0
847      8705 W2=U1+8333.333
848      8710 FOR J=1 TO U6
849      8715 IF J=1 THEN W19='NEW' ELSE W19='OVERLAY'
850      8720 IF Y19='-1' THEN 8915
851      8725 IF J=1 THEN 8730 ELSE 8755
852      8730 FOR K=1 TO V1
853      8735 V8=R(K,1)
854      8740 FOR J1=1 TO V8 X(J1+U7)=T(K,J1)+(K-1)*8333.33
855      8745 U7=U7+V8
856      8750 NEXT K
857      8755 IF J=1 THEN IF V3=1 THEN 8810
858      8760 IF V4=1 THEN IF J=2 AND V3=1 OR J=1 THEN 8850
859      8765 REM PLOT HALF CYCLES
860      8770 V7=V1*60
861      8775 FOR J1=1 TO U7
862      8780 X(J1)=J1*138.8889
863      8785 IF I5>1 THEN Y(J1)=E1*ABS(SIN(I5*J1*1.3888889E-4)) ELSE Y(J1)=E1
864      8790 NEXT J1
865      8795 W4=U7
866      8800 W1=1
867      8805 GO TO 8905
868      8810 W1=-9
869      8815 U7=0
870      8820 FOR K=1 TO V1
871      8825 V8=R(K,1)
872      8830 FOR J1=1 TO V8 Y(J1+U7)=E(K,J1)
873      8835 U7=U7+V8
874      8840 NEXT K
875      8845 GO TO 8905
876      8850 IF V4=1 AND V6=1 THEN W1=-9 ELSE W1=4
877      8855 Z8=W4/A2*.5
878      8860 U7=0
879      8865 FOR K=1 TO V1
880      8870 V8=R(K,1)
881      8875 IF V4=1 AND V6=1 THEN 8890
882      8880 FOR J1=1 TO V8 Y(J1+U7)=I(K,J1)*Z8
883      8885 GO TO 8895
884      8890 FOR J1=1 TO V8 Y(J1+U7)=I(K,J1)
885      8895 U7=U7+V8
886      8900 NEXT K
887      8905 GOSUB 9000
888      8910 NEXT J
889      8915 IF V2>0 THEN V2=3
890      8920 IF V2>0 THEN GOSUB 11000
891      8925 RETURN

```

PITS-19

```

0892 C *****
0893 C *
0894 C * PEPSUB. APPROPRIATELY HARDWIRED. *
0895 C * *
0896 C *****
0897 9000 REM MODIFIED VERSION OF STUELAND'S PEPSUB
0898 9002 REM TAKES JP TO 1000 FONTS; SPECIFIC
0899 9018 IF Z1=0 THEN 9116
0900 9020 LET Z2=0
0901 9022 LET Z1$='XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX'
0902 9024 LET Z3$='0.0000000000 0.0000000000'
0903 9028 'A) ENABLE HARD COPY PLOTTING'
0904 9030 INPUT Z2$
0905 9032 IF Z2$='-1' THEN 9086
0906 9034 IF Z2$='-2' THEN LET Z2$='YES'
0907 9036 IF Z2$='NO' OR Z2$='YES' THEN 9042
0908 9038 ' '
0909 9040 GO TO 9038
0910 9042 IF Z2$='NO' THEN LET Z7$=' ' ELSE LET Z7$='QGSP.PT'
0911 9044 IF Z2$='NO' THEN 9078
0912 9046 Z2$='SMALL'
0913 9058 Z2=10.8
0914 9064 Z4$='YES'
0915 9078 ' '
0916 9082 OPEN PLOT FOR SYMBOLIC OUTPUT AS FILE 9
0917 9084 LET Z9=0
0918 9088 IF Z7$=' ' THEN PRINT ON 9 IN IMAGE Z1$;Z7$
0919 9090 IF Z7$=' ' THEN 9110
0920 9106 LET Z5$='PLOTTER PEN/LIO'
0921 9108 PRINT ON 9 IN IMAGE Z1$;Z5$
0922 9110 LET Z2$='BXQT CHEMISTRY*WALTERS.BIGGER-PEP'
0923 9112 PRINT ON 9 IN IMAGE Z1$;Z2$
0924 9114 PRINT ON 9 IN IMAGE 'XX.ZZZX';Z2
0925 9116 LET Z1=Z1+1
0926 9117 LET X5=0
0927 9118 IF Z4=2 THEN 9704
0928 9120 LET Z9=0
0929 9122 Z9=X5
0930 9132 LET Z3=0
0931 9134 IF Z6='NEW' THEN Z3=1
0932 9136 IF Z6='OVERLAY' THEN LET Z3=2
0933 9140 IF Z6='DONE' THEN LET Z3=4
0934 9142 IF Z6='CLOSE' THEN LET Z3=4
0935 9144 IF Z3=0 THEN 9788
0936 9146 IF Z3=2 AND Z4=2 THEN 9160
0937 9148 IF Z3=2 THEN 9160
0938 9150 IF Z3=2 AND Z4=1 THEN 9160
0939 9152 ' '
0940 9154 'YOU CANNOT DO AN OVERLAY WITHOUT AT LEAST'
0941 9156 ' ONE NEW PLOT '
0942 9158 GO TO 9790
0943 9160 LET Z9=Z3
0944 9162 ON Z3 GO TO 9168,9164,9168,9166
0945 9164 PRINT ON 9 IN IMAGE Z1$;'OVERLAY'
0946 9166 GO TO 9274
0947 9168 PRINT ON 9 IN IMAGE Z1$;'NEW PLOT'
0948 9186 LET Z9=1

```

PITS-20

```

949 9192 REM          -- TITLE --
950 9194 IF Z9<=0 THEN 9216
951 9198 Z2:=W2$
952 9202 IF Z2#'-3' THEN 9216
953 9212 PRINT ON 9 IN IMAGE Z1$:Z2$
954 9214 GO TO 9224
955 9216 PRINT ON 9 IN IMAGE 'XXXXX':PLOT$
956 9218 PRINT ON 9 IN IMAGE 'XXXXX':Z1
957 9220 REM          -- LABEL FOR X-AXIS --
958 9222 IF Z9<=0 THEN 9244
959 9224 Z2$='TIME IN MICROSECONDS'
960 9240 PRINT ON 9 IN IMAGE Z1$:Z2$
961 9242 GO TO 9250
962 9244 PRINT ON 9 IN IMAGE Z1$:'X AXIS'
963 9246 IF Z9<=0 THEN 9268
964 9248 REM          -- Y-AXIS LABEL --
965 9250 Z2$=W3$
966 9264 PRINT ON 9 IN IMAGE Z1$:Z2$
967 9266 GO TO 9274
968 9268 PRINT ON 9 IN IMAGE Z1$:'Y AXIS'
969 9270 IF Z9<=0 THEN 9298
970 9272 REM          -- SYMBOL AT EACH DATA POINT --
971 9274 Z8=-2
972 9298 PRINT ON 9 IN IMAGE 'XX':-9'
973 9300 IF Z9<=0 THEN 9338
974 9302 REM          -- LINE TO CONNECT DATA POINTS --
975 9304 Z7=W1
976 9320 IF Z7=-2 OR Z7=-3 THEN 9338
977 9322 IF Z7<0 THEN 9338
978 9334 PRINT ON 9 IN IMAGE 'XX':Z7
979 9336 GO TO 9346
980 9338 PRINT ON 9 IN IMAGE 'XX':-9'
981 9340 IF Z9<0 AND Z3=2 THEN 9632
982 9342 IF Z9<=0 AND Z3<>2 THEN 9384
983 9344 REM          -- MAXIMUM AND MINIMUM --
984 9346 IF Z3=2 THEN 9574
985 9348 Z8=W2
986 9362 Z7=W3
987 9376 IF Z7=Z8 THEN PRINT '** THE TIME MAX. AND MIN. WERE EQUAL-ERROR.'
988 9377 IF Z7=Z8 THEN Z9=-1
989 9378 IF Z9=-1 THEN 9384
990 9380 PRINT ON 9 IN IMAGE Z3$:Z7,Z8
991 9382 GO TO 9390
992 9384 PRINT ON 9 IN IMAGE 'XXX':O O'
993 9386 GO TO 9432
994 9388 REM          -- MAX & MIN ON Y AXIS
995 9390 Z4=0
996 9392 Z8=W4
997 9410 Z7=W5
998 9420 IF Z7<>Z8 THEN 9428
999 9422 ' '
1000 9423 '** VERTICAL AXIS MAX. AND MIN. WERE EQUAL-ERROR.'
1001 9425 Z9=-1
1002 9427 GO TO 9432
1003 9428 PRINT ON 9 IN IMAGE Z3$:Z7,Z8
1004 9430 GO TO 9436
1005 9432 PRINT ON 9 IN IMAGE 'XXX':O O'

```

PITS-21

```

1006 9434 REM          -- PAGE SIZE --
1007 9436 IF Z7$=' ' AND Z9=0 THEN LET Z9=0
1008 9437 IF Z9=0 THEN 9488
1009 9438 Z2$='NUMBER'
1010 9444 IF Z2$='-1' OR Z2$='-2' OR Z2$='-3' THEN 9488
1011 9446 IF Z2$='NUMBER' THEN 9496
1012 9488 PRINT ON 9 IN IMAGE Z1$:'NUMBER'
1013 9490 PRINT ON 9 IN IMAGE Z3$:Z2,Z2
1014 9492 IF Z9=-1 THEN 9632
1015 9494 GO TO 9574
1016 9496 PRINT ON 9 IN IMAGE Z1$:'NUMBER'
1017 9497 REM SET LENGTH OF X OR TIME AXIS
1018 9498 Z6=(Z2-3)*47+3
1019 9500 IF Z6>50 THEN Z6=50
1020 9502 IF Z6=50 THEN PRINT '** TIME AXIS TRUNCATED.'
1021 9514 REM SET LENGTH OF Y OR ELECTRIC AXIS.
1022 9516 Z7=Z2
1023 9538 PRINT ON 9 IN IMAGE Z3$:Z6,Z7
1024 9574 Z4=46
1025 9576 IF Z4<2 OR Z4>1000 THEN 9578 ELSE 9590
1026 9578 PRINT '** LESS THAN 2 OR MORE THAN 1000 POINTS TO BE PLOTTED.'
1027 9580 PRINT '      ABORT PLOT.'
1028 9582 GO TO 9632
1029 9590 IF Z9<-1 THEN PRINT ON 9 IN IMAGE Z1$:'DATAFOLLOWS' ELSE 9632
1030 9592 FOR Z5=1 TO Z4
1031 9594 PRINT ON 9 IN IMAGE Z3$:X(Z5),Y(Z5)
1032 9596 NEXT Z5
1033 9598 LET Z4=Z4+1
1034 9600 GO TO 9634
1035 9632 PRINT ON 9 IN IMAGE Z1$:'EARLY ESCAPE'
1036 9634 IF Z4<3 THEN LET Z9=-1
1037 9636 PRINT ON 9 IN IMAGE 'XXXXX':'-1 -1'
1038 9638 IF Z9=-1 THEN PRINT ON 9 IN IMAGE Z1$:'NODATA'
1039 9640 IF Z9<-1 THEN PRINT ON 9 IN IMAGE Z1$:'ENDOFDATA'
1040 9642 LET Z4=0
1041 9444 REM          -- END OF ONE PLOT --
1042 9446 REM          -- CHECK THE STATUS OF THE PLOT --
1043 9448 REM          -- RETURN FOR 'NEW' --
1044 9450 IF Z9<-1 THEN LET Z4=23
1045 9451 IF Z9=-1 AND Z3=2 THEN LET Z4=1
1046 9452 IF Z9=-1 THEN 9486
1047 9454 IF Z3=2 THEN 9666
1048 9462 RETURN
1049 9464 REM          -- 'RETURN' FOR LEAVING BASIC --
1050 9466 LET Z2$='GEOF'
1051 9468 PRINT ON 9 IN IMAGE Z1$:Z2$
1052 9470 ' '
1053 9472 CLOSE 9
1054 9474 'FILE HAS BEEN CLOSED'
1055 9476 IF Z1$='CLOSE' THEN 9496
1056 9478 'EXIT FROM BASIC'
1057 9480 EXEC 'WASG,A PLOT.
1058 9482 EXEC 'BADD,P PLOT.
1059 9484 STOP
1060 9486 IF Z3<-1 THEN LET Z4=Z3 ELSE LET Z4=0
1061 9488 ' '
1062 9490 'ESCAPE RETURN'

```


PITS-22

```
1063 9692 ' '
1064 9694 RETURN
1065 9696 'NO EXIT FROM BASIC'
1066 9698 'THIS SHOULD BE THE LAST RETURN FROM THE PEP SUBROUTINE'
1067 9700 LET Z4=5
1068 9702 RETURN
1069 9704 'FILE HAS CLOSED ON THE LAST CALL'
1070 9706 'NO MORE PEP'SUB PLOTS--SORRY.'
1071 9708 GO TO 9688
1072 9788 PRINT 'ILLEGAL PLOT TYPE: MUST BE NEW, OVERLAY, DONE, OR CLOSE.'
1073 9790 Z9=-1
1074 9792 IF Z4>=1 THEN Z3=2
1075 9794 PRINT ON 9 IN IMAGE Z1: 'NEW PLOT'
1076 9796 GO TO 9216
```

PITS-23

```

1077 C *****
1078 C *
1079 C * MINILOT, APPROPRIATELY HARDWIRED.
1080 C *
1081 C *****
1082 10000 REM THIS IS A MODIFICATION OF STUCLAND'S MINILOT.
1083 10003 REM HARDWIRING IS SPECIFIC TO PROGRAM CHARJUP
1084 10009 LET Z0=Z0+1
1085 10012 LET Y2$=""
1086 10015 IF Z0=1 THEN 10037
1087 10018 DIM Z(60,30)
1088 10021 LET Y8$=""
1089 10024 LET X1=30
1090 10027 Y1$=W1$
1091 10036 IF Y1$="-2" THEN LET Y1$="NEW"
1092 10039 IF Y1$="-1" THEN 10933
1093 10042 IF Y1$="OVERLAY" AND Y8$="NEW" THEN 10186
1094 10045 IF Y1$<>"OVERLAY" THEN 10060
1095 10048
1096 10051 ** YOU CANNOT HAVE AN OVERLAY WITHOUT AT LEAST ONE NEW PLOT
1097 10054 ' SHOOT THE PROGRAMMER--IT'S HIS FAULT!!!
1098 10056 Y1$="-1"
1099 10057 GO TO 10933
1100 10060 IF Y1$<>"NEW" THEN 10054
1101 10061 LET Y8$=""
1102 10063 FOR Y7=1 TO X1
1103 10066 FOR Y8=1 TO 40
1104 10069 LET Z(Y8,Y7)=5
1105 10072 NEXT Y8
1106 10075 NEXT Y7
1107 10078 LET Y7=5
1108 10081 Y2$="YES"
1109 10090 REM SET TITLE
1110 10100 Y3$=W2$
1111 10120 REM X AXIS LABEL
1112 10130 Y4$="TIME IN MICROSECONDS"
1113 10140 REM Y AXIS LABEL
1114 10150 Y5$=W3$
1115 10186 REM SYMBOL--ENTERED AS NUMERICAL EQUIVALENT.
1116 10189 REM SEE BASIC MANUAL P. 7-5
1117 10192 Y8=1
1118 10195 Y7=W1
1119 10198 IF Y7=14 THEN Y6$="I"
1120 10201 IF Y7=10 THEN Y6$="E"
1121 10204 IF Y7>14 AND Y7<10 THEN Y6$="X"
1122 10207 X$=Y6$
1123 10231 IF Y1$="OVERLAY" THEN 10396
1124 10234 REM MAX X AXIS
1125 10237 Y2=W2
1126 10252 REM MIN X AXIS
1127 10255 Y1=W3
1128 10264 IF Y1>Y2 THEN EXCHANGE Y1,Y2
1129 10267 IF Y2>Y1 THEN 10276
1130 10270 '## THE MAX AND MIN X (TIME) CANNOT BE EQUAL
1131 10272 ' ABORT PLOTS.
1132 10273 Y1$="-1"
1133 10274 GO TO 10933

```

PITS-24

```

1134 10274 REM MAX Y AXIS
1135 10279 Y4=W4
1136 10291 REM MIN Y AXIS
1137 10294 Y3=W5
1138 10306 IF Y3:Y4 THEN EXCHANGE Y3,Y4
1139 10309 IF Y4>Y3 THEN 10396
1140 10312 ' '
1141 10315 '** THE MAX AND MIN Y (ELECTRICAL) AXIS CANNOT BE EQUAL.'
1142 10318 GO TO 10272
1143 10393 REM SET NUMBER OF POINTS
1144 10396 Y8=W6
1145 10400 IF Y8<2 OR Y8>250 THEN 10411 ELSE 10423
1146 10411 '** TOO MANY OR TOO FEW POINTS IN MINIPLOT.'
1147 10414 GO TO 10272
1148 10417 REM ----- SORT ARRAYS -----
1149 10423 FOR Y9=1 TO Y8
1150 10426 FOR Y0=Y9 TO Y8
1151 10429 IF X(Y9)<X(Y0) THEN 10438
1152 10432 EXCHANGE X(Y9),X(Y0)
1153 10435 EXCHANGE Y(Y9),Y(Y0)
1154 10438 NEXT Y0
1155 10441 NEXT Y9
1156 10444 IF Y18='OVERLAY' THEN 10514
1157 10450 IF Y1<Y2 AND Y3<Y4 THEN 10508
1158 10453 ' '
1159 10456 '** THE DIFFERENCE BETWEEN THE LARGEST & SMALLEST VALUES IS TOO SHAL
1160 10459 PRINT ' X MIN='Y1
1161 10462 PRINT ' X MAX='Y2
1162 10465 PRINT ' Y MIN='Y3
1163 10468 PRINT ' Y MAX='Y4
1164 10471 ' '
1165 10474 ' ERROR RETURN'
1166 10477 ' '
1167 10508 LET Y1=Y1-(Y2-Y1)/59
1168 10509 LET Y3=Y3-(Y4-Y3)/(X1-1)
1169 10510 LET Y5=(Y2-Y1)/60
1170 10513 LET Y6=(Y4-Y3)/X1
1171 10516 IF Y18='OVERLAY' THEN LET Y1=Y1-(Y2-Y1)/59
1172 10517 IF Y18='OVERLAY' THEN LET Y3=Y3-(Y4-Y3)/(X1-1)
1173 10549 LET X2=0
1174 10552 FOR Y9=1 TO Y8
1175 10555 IF X(Y9)<Y1 THEN 10717
1176 10561 IF X(Y9)>Y2 THEN 10717
1177 10564 IF X2=0 THEN 10588
1178 10567 LET X0=INF((X(Y9)-Y1)/Y5+.5)
1179 10570 LET Y0=INF((Y(Y9)-Y3)/Y6+.5)
1180 10573 IF X0=0 OR Y0=0 THEN 10717
1181 10576 IF Y0<1 OR Y0>X1 THEN 10607
1182 10579 LET Z(X0,Y0)=Y7
1183 10582 LET X2=Y9
1184 10585 GO TO 10717
1185 10588 LET X3=X(Y9)-X(X2)
1186 10591 LET X4=ABS(Y(Y9)-Y(X2))
1187 10594 IF X3<(Y5/2) AND X4.(Y6/2) THEN 10717
1188 10597 LET X3=INF((X(Y9)-Y1)/Y5+.5)
1189 10600 LET X4=INF((Y(Y9)-Y3)/Y6+.5)
1190 10603 IF X4<1 OR X4.X1 THEN 10607

```

PITS-25

```

1191 10406 IF X3=X0 AND X4=Y0 THEN 10717
1192 10409 IF Z(X3,X4)=5 THEN LET Z(X3,X4)=Y7
1193 10412 IF Z(X3,X4)=34 THEN LET Z(X3,X4)=Y7
1194 10415 GO TO 10717
1195 10487 IF Y0=1 OR X4=1 THEN LET X4=1 ELSE LET X4=X1
1196 10490 IF X2=0 AND Z(X3,X4)=5 AND Z(X3,X4)=34 THEN 10708
1197 10493 IF X2=0 AND Z(X0,X4)=5 AND Z(X0,X4)=34 THEN 10708
1198 10496 IF X4=X1 THEN 10705
1199 10499 IF X2=0 THEN LET Z(X0,1)=7 ELSE LET Z(X3,1)=7
1200 10702 GO TO 10708
1201 10705 IF X2=0 THEN LET Z(X0,X1)=6 ELSE LET Z(X3,X1)=6
1202 10708 LET X0=X3
1203 10711 LET Y0=X4
1204 10714 LET X2=Y9
1205 10717 NEXT Y9
1206 10718 LET Y1=Y1+(Y2-Y1)/60
1207 10719 LET Y3=Y3+(Y4-Y3)/X1
1208 10720 IF F(2)<0 THEN 10927
1209 10723 GOSUB 11950
1210 10729 IF Y3='PLOT' THEN 10750
1211 10732 LET X5=Y3
1212 10735 LET X0=LEN(X5)
1213 10738 LET Y0=INP((72-X0)/2+.5)
1214 10741 PRINT TAB(Y0);
1215 10744 PRINT X5
1216 10747 GO TO 10753
1217 10750 PRINT TAB(30);'PLOT '120
1218 10753 PRINT;' X';
1219 10754 FOR X0=1 TO 5
1220 10759 PRINT '+'-----';
1221 10762 NEXT X0
1222 10765 LET X5='
1223 10768 LET Y5=Y5
1224 10771 LET Y0=LEN(Y5)
1225 10774 LET X0=INP((X1-Y0)/2+.5)
1226 10777 LET Y7=ADD$(X5,Y5,X0)
1227 10780 LET Y9=4
1228 10783 FOR Y0=1 TO X1
1229 10786 LET X5=Y5+'
1230 10789 FOR X0=1 TO 60
1231 10792 LET X2=X1+1-Y0
1232 10795 LET Y0=Z(X0,X2)
1233 10798 LET X5=PUT$(Y5,X0,Y8)
1234 10801 LET Y5=X5
1235 10804 NEXT X0
1236 10807 LET Y5=Y7
1237 10810 LET X0=GET(Y5,Y0)
1238 10813 LET Y5='
1239 10816 LET Y6=PUT$(Y5,1,X0)
1240 10819 PRINT Y6;
1241 10822 LET Y9=Y9+1
1242 10825 IF Y9=5 THEN LET Y9=0
1243 10828 IF Y0=1 AND Y0=X1 THEN 10840
1244 10831 IF Y0=1 THEN LET Y8=Y4 ELSE LET Y8=Y3
1245 10834 PRINT IN IMAGE '#####';Y8;
1246 10837 GO TO 10849
1247 10840 IF Y9<0 THEN 10855

```

PITS-26

```

1248 10843 LET X0=Y4-(Y0-1)*Y6
1249 10846 PRINT IN IMAGE '0.000000':X0;
1250 10849 PRINT '+';
1251 10852 GO TO 10858
1252 10855 PRINT ' ' ;
1253 10858 PRINT X$
1254 10861 NEXT Y0
1255 10864 PRINT ' ' X';
1256 10867 FOR X0=1 TO 5
1257 10870 PRINT '+-----';
1258 10873 NEXT X0
1259 10876 FOR X0=1 TO 4
1260 10879 LET Y9=Y1+12*X0*Y5
1261 10882 LET Y8=10+X0*12-4
1262 10885 PRINT TAB(Y8);
1263 10888 PRINT IN IMAGE '0.000000':Y9;
1264 10891 NEXT X0
1265 10894 ' '
1266 10897 PRINT TAB(6);
1267 10900 PRINT IN IMAGE '0.000000':Y1;
1268 10903 PRINT TAB(63);
1269 10906 PRINT IN IMAGE '0.000000':Y2
1270 10909 LET X$=Y4$
1271 10912 LET X0=LEN(X$)
1272 10915 LET Y0=INT((72-X0)/2+.5)
1273 10918 PRINT TAB(Y0);Y4$
1274 10921 ' '
1275 10924 'NORMAL RETURN'
1276 10927 LET Y8$='NEW'
1277 10930 RETURN
1278 10933 ' '
1279 10936 'ESCAPE RETURN'
1280 10939 RETURN

```

PITS-27

```

1281 C *****
1282 C *
1283 C * PRINT ROUTINE.
1284 C *
1285 C *****
1286 11000 REM PRINTED OUTPUT ROUTINE
1287 11005 AS=U2$
1288 11010 GOSUB 11950
1289 11015 U3=LEN(AS)
1290 11020 PRINT TAB(35-INT(U3/2+.5));U2$
1291 11025 IF F(1)=1 THEN PRINT ON 7:TAB(41-INT(U3/2+.5));U2$
1292 11030 FOR K1=1 TO 2 PRINT ' '
1293 11035 IF F(1)=1 THEN PRINT ON 7 IN FORM '^^':
1294 11040 FOR K=1 TO U1
1295 11045 IF K>1 THEN GOSUB 11950
1296 11050 PRINT TAB(29);'HALF-CYCLE';R(K,4)
1297 11055 IF F(1)=1 THEN PRINT ON 7:TAB(35);'HALF-CYCLE';R(K,4)
1298 11060 FOR K1=1 TO 2 PRINT ' '
1299 11065 IF F(1)=1 THEN PRINT ON 7 IN FORM '^^':
1300 11070 ON U2 GO TO 11075,11310,11485
1301 11075 U5$='2(4X.X 385X 184X.XZ38)4X.X 285X 184X.XX'
1302 11080 U6$='3(4X.X 385X 284X.XZ58)'
1303 11085 FOR K1=1 TO 3
1304 11090 K2=(K1-1)*24
1305 11095 PRINT TAB(K2);' T E I'
1306 11100 K2=K2+(K1-1)*4
1307 11105 IF F(1)=1 THEN PRINT ON 7:TAB(K2);' T E I'
1308 11110 NEXT K1
1309 11115 PRINT ' '
1310 11120 IF F(1)=1 THEN PRINT ON 7: ' '
1311 11125 U3=MOD(R(K,1),3)
1312 11130 U4=INT(R(K,1)/3+.001)
1313 11135 REM +.001 ELIMINATES ROUND OFF ERROR.
1314 11140 IF U3=0 THEN U5=U4 ELSE U5=U4+1
1315 11145 K9=U3+2*U4
1316 11150 FOR K1=1 TO U4
1317 11155 B1=T(K,A1)
1318 11160 B2=E(K,A1)
1319 11165 B3=I(K,A1)
1320 11170 B4=T(K,A1+U5)
1321 11175 B5=E(K,A1+U5)
1322 11180 B6=I(K,A1+U5)
1323 11185 B7=T(K,A1+K9)
1324 11190 B8=E(K,A1+K9)
1325 11195 B9=I(K,A1+K9)
1326 11200 PRINT IN FORM U5:B1,B2,B3,B4,B5,B6,B7,B8,B9
1327 11205 IF F(1)=1 THEN 11210 ELSE 11215
1328 11210 PRINT ON 7 IN FORM U6:B1,B2,B3,B4,B5,B6,B7,B8,B9
1329 11220 IF U3=0 THEN 11285
1330 11225 B1=T(K,U5)
1331 11230 B2=E(K,U5)
1332 11235 B3=I(K,U5)
1333 11240 IF U3=1 THEN 11245 ELSE 11260
1334 11245 PRINT IN FORM U5:B1,B2,B3
1335 11250 IF F(1)=1 THEN PRINT ON 7 IN FORM U6:B1,B2,B3
1336 11255 GO TO 11295
1337 11260 B4=T(K,2*U5)

```

PITS-23

```

1338      11265 B5=E(K,2*V5)
1339      11270 B6=I(K,2*V5)
1340      11275 PRINT IN FORM V5:R1,B2,B3,B4,B5,B6
1341      11280 IF F(1)=1 THEN PRINT ON 7 IN FORM V6:R1,B2,B3,B4,B5,B6
1342      11285 GOSUB 11295
1343      11290 GO TO 11695
1344      11295 FOR N1=1 TO 5 PRINT ' '
1345      11300 IF F(1)=1 THEN PRINT ON 7 IN FORM '/////':
1346      11305 RETURN
1347      11310 PRINT TAB(29):'BREAK VALUES'
1348      11315 PRINT ' '
1349      11320 PRINT TAB(17):'BREAK' TAB(25):'VOLTAGE' TAB(35):'CURRENT' TAB(45):
1350      11325 PRINT 'TIME'
1351      11330 PRINT ' '
1352      11335 IF F(1)<1 THEN 11365
1353      11340 PRINT ON 7: TAB(35):'BREAK VALUES'
1354      11345 PRINT ON 7: ' '
1355      11350 PRINT ON 7: TAB(23):'BREAK' TAB(31):'VOLTAGE' TAB(41):
1356      11355 PRINT ON 7: 'CURRENT' TAB(51):'TIME'
1357      11360 PRINT ON 7: ' '
1358      11365 V5='19BXX 5B5X 3B5X.XX 3B4X.X'
1359      11370 V6='25BXX 5B5X 3B5X.XX 3B4X.X'
1360      11375 J2=K
1361      11380 GOSUB 3095
1362      11385 A1=R(K,2)
1363      11390 IF A1<1 THEN 11465
1364      11395 A4=1
1365      11400 FOR K1=1 TO A1
1366      11405 A2=S(K,K1)
1367      11410 A3=R(K,1)
1368      11415 IF A3=0 THEN 11475
1369      11420 FOR K2=A4 TO A3
1370      11425 IF T(K,K2)=A2 THEN 11430 ELSE 11455
1371      11430 A4=K2+2
1372      11435 PRINT IN FORM V5:K1,E(K,K2),I(K,K2),T(K,K2)
1373      11440 IF F(1)=1 THEN PRINT ON 7 IN FORM V6:K1,E(K,K2),I(K,K2),T(K,K2)
1374      11445 IF A4>A3 THEN 11475 ELSE 11460
1375      11450 IF K1=A1 THEN 11465
1376      11455 NEXT K2
1377      11460 NEXT K1
1378      11465 GOSUB 11295
1379      11470 GO TO 11695
1380      11475 'OUT OF POINTS BEFORE ALL BREAKS FOUND.'
1381      11480 GO TO 11465
1382      11485 PRINT TAB(20):'PARAMETER DUMP'
1383      11490 PRINT ' '
1384      11495 V5='R(FORWARD)=##### R(REV. BIAS)=##### C(UF)= XX.XXXX'
1385      11500 PRINT IN IMAGE V5:R1,K2,C1
1386      11505 IF F(1)=1 THEN 11510 ELSE 11525
1387      11510 PRINT ON 7: TAB(34):'PARAMETER DUMP'
1388      11515 PRINT ON 7: ' '
1389      11520 PRINT ON 7 IN IMAGE V5:R1,R2,C1
1390      11525 V5='L(HENRIES)= XXX.XXX GAHHA( DEG)= XXX.XX N BREAKS= XX'
1391      11530 J2=K
1392      11535 GOSUB 3095
1393      11540 J2=R(K,2)
1394      11545 PRINT IN IMAGE V5:L1,S4*360/I4,J2

```

FITS-29

```

1395 11550 IF F(1)=1 THEN PRINT ON 7 IN IMAGE VS:L1.54*340/14.J2
1396 11555 VS=Z0= 0000000000 S=2= 0000000000 S= 0000000000
1397 11560 PRINT IN IMAGE VS:SJ.S1.S2
1398 11565 IF F(1)=1 THEN PRINT ON 7 IN IMAGE VS:SJ.S1.S2
1399 11570 PRINT 'E(XHFR)='E1:TAB(22) DISCHARGE DURATION='ITB
1400 11575 PRINT 'IO AT START ='R(K,7)
1401 11580 PRINT 'IO AT END ='R(K,8)
1402 11585 PRINT 'EO AT START ='R(K,5)
1403 11590 PRINT 'EO AT END ='R(K,6)
1404 11593 PRINT 'AVG. I(MA) ='R(K,9)
1405 11595 IF F(1)<1 AND V=1 THEN 11600 ELSE IF F(1)>1 THEN 11690
1406 11600 PRINT ON 7 'E(XHFR)='E1:TAB(22) DISCHARGE DURATION='ITB
1407 11605 PRINT ON 7 'IO AT START ='R(K,7)
1408 11610 PRINT ON 7 'IO AT END ='R(K,8)
1409 11615 PRINT ON 7 'EO AT START ='R(K,5)
1410 11620 PRINT ON 7 'EO AT END ='R(K,6)
1411 11623 PRINT ON 7 'AVG. I(MA) ='R(K,9)
1412 11625 IF V=0 THEN 11630 ELSE 11690
1413 11630 IF V4=1 AND V6=1 THEN 11655
1414 11635 PRINT ON 7 'FULL SCALE V='V4
1415 11640 IF V4=1 THEN 11645 ELSE 11660
1416 11645 PRINT ON 7 'FULL SCALE I='I2/A18W4#2
1417 11650 GO TO 11660
1418 11655 PRINT ON 7 'FULL SCALE I='I4
1419 11660 IF V4=1 AND V6=1 THEN 11685
1420 11665 PRINT 'FULL SCALE V='V4
1421 11670 IF V4=1 THEN 11675 ELSE 11690
1422 11675 PRINT 'FULL SCALE I='I2/A18W4#2
1423 11680 GO TO 11690
1424 11685 PRINT 'FULL SCALE I='I4
1425 11690 GOSUB 11295
1426 11695 NEXT K
1427 11700 RETURN
1428 11950 '
1429 11955 'HOME'
1430 11960 INPUT V18
1431 11965 RETURN

```


PITS-30

```

1432 C *****
1433 C *
1434 C * TERMINATION ROUTINE.
1435 C *
1436 C *****
1437 12000 REM TERMINATION ROUTINE
1438 12002 PRINT ' '
1439 12004 GO TO 12070
1440 12005 IF F(1)=1 THEN CLOSE 7
1441 12010 IF Z1=0 THEN 12015 ELSE 12060
1442 12015 Z3=4
1443 12020 PRINT 'DO YOU WISH TO VIEW PLOT NOW OR'
1444 12025 PRINT 'DO YOU WISH TO STORE SAME FOR LATER?'
1445 12030 PRINT 'INPUT "NOW" OR "LATER"; DEFAULT= NOW'
1446 12035 INPUT Z4
1447 12040 IF Z4='NOW' OR Z4='-2' THEN Z4='DONE' ELSE 12050
1448 12045 GO TO 9666
1449 12050 IF Z4='LATER' THEN Z4='CLOSE' ELSE 12020
1450 12055 GOSUB 9666
1451 12060 PRINT 'THANK YOU FOR YOUR PATRONAGE.'
1452 12065 STOP
1453 12070 PRINT 'TERMINATE OR KEEP RUNNING'
1454 12075 INPUT A$
1455 12080 IF A$='TERMINATE' THEN 12005
1456 12085 IF A$='KEEP RUNNING' THEN RETURN
1457 12090 GO TO 12070

```

PITS-31

```

1458 C *****
1459 C *
1460 C * CHOOSE HALF-CYCLE
1461 C *
1462 C *****
1463 14000 REM HALF CYCLE SELECTION
1464 14003 PRINT '
1465 14005 PRINT 'WHICH HALF CYCLE DO YOU WISH TO USE'
1466 14010 INPUT V1
1467 14015 IF V1=-2 THEN V1=1
1468 14020 IF V1<1 OR V1>4 OR V1<>INT(V1) THEN 14005
1469 14025 RETURN
1470 C *****
1471 C *
1472 C * CHARGING INITIALIZATION--START OF HALF-CYCLE.
1473 C *
1474 C * OPTIONS:
1475 C *
1476 C * 1) INPUT TYPED IN DURING INITIALIZATION GIVES INITIAL
1477 C * CONDITIONS.
1478 C * 2) PRIOR RESULT IN CHOSEN HALF-CYCLE I.E. LAST DATA POINT
1479 C * IN THE PARTICULAR HALF-CYCLE LEFT OVER FROM A PREVIOUS
1480 C * CALCULATION GIVES INITIAL CONDITIONS.
1481 C * 3) RESULT OF PREVIOUS HALF-CYCLE I.E. LAST DATA POINT IN NEXT
1482 C * LOWER NUMBERED HALF-CYCLE GIVES INITIAL CONDITIONS.
1483 C *
1484 C * DEFAULT=3
1485 C *
1486 C *****
1487 14030 REM CYCLE INITIALIZATION
1488 14033 PRINT '
1489 14035 PRINT 'BASE INITIAL CONDITIONS ON 1) TYPED IN INPUT'
1490 14040 PRINT TAB(27);'2) PRIOR RESULT IN THIS HALF-CYCLE OR'
1491 14045 PRINT TAB(27);'3) RESULT OF PREVIOUS HALF-CYCLE.'
1492 14050 PRINT 'CHOOSE 1, 2, OR 3'
1493 14055 INPUT V9
1494 14060 IF V9=-2 THEN V9=3
1495 14065 IF V9<1 OR V9>3 OR V9<>INT(V9) THEN 14035
1496 14066 IF V9=2 THEN IF R(V1,3)=0 THEN 14725
1497 14067 IF V9=3 THEN IF V1<1 THEN IF R(V1-1,3)=0 THEN 14725
1498 14068 IF V9=3 THEN IF V1=1 THEN IF R(4,3)=0 THEN 14725
1499 14070 R(V1,9)=0
1500 14075 U7=-1
1501 14080 K9=0
1502 14085 G3=1
1503 14090 ON V9 GO TO 14095,14125,14150
1504 14095 T(V1,1)=T(V1,2)=T=7
1505 14100 E(V1,1)=I(V1,1)=0
1506 14105 I(V1,2)=I2=I1
1507 14110 E(V1,2)=E6=E5
1508 14115 A1=2
1509 14120 GO TO 14175
1510 14125 T(V1,1)=T=0
1511 14130 E(V1,1)=E6=R(V1,6)
1512 14135 I(V1,1)=I2=R(V1,8)
1513 14140 A1=1
1514 14145 GO TO 14175

```

PITS-32

```

1515 14150 IF V1=1 THEN A1=4 ELSE A1=V1-1
1516 14155 T(V1,1)=T=0
1517 14160 E(V1,1)=E6-R(A1,4)
1518 14165 I(V1,1)=I2=R(A1,8)
1519 14170 A1=1
1520 14175 IF V9<3 THEN R(V1,4)=V1 ELSE 14195
1521 14180 R(V1,5)=E6
1522 14185 R(V1,7)=I2
1523 14190 GO TO 14205
1524 14195 IF V1<1 THEN R(V1,4)=R(V1-1,4)+1 ELSE R(V1,4)=R(4,4)+1
1525 14200 GO TO 14180
1526 14205 IF E6<0 OR V9=1 THEN 14280
1527 14210 IF V9=2 THEN V8=V1 ELSE V8=V1-1
1528 14215 IF V8=0 THEN V8=4
1529 14220 V7=R(V8,1)-1
1530 14225 V7=TS-(8333.33-T(V8,V7))
1531 14230 REM V7 NOW = TIME LEFT FOR DISCHARGE COMPLETION
1532 14235 CALL FNP(R1,L1,0)
1533 14240 A1=A1+1
1534 14245 T(V1,A1)=V7
1535 14250 E7=E6-E(V1,A1)=0
1536 14255 G2=V7
1537 14260 CALL FNT(0,I2,E6,R1,L1,0)
1538 14265 I3=I2
1539 14270 I2=I(V1,A1)=FNI(G2,R1)
1540 14275 GOSUB 14715
1541 14280 IF I3>1 THEN A2=E1*SIN(I5*T*1E-6) ELSE A2=E1*COS(I5*T*1E-6)
1542 14285 G1=T
1543 14290 IF I2=0 AND E6<A2 OR I2=0 THEN GOSUB 850 ELSE 14300
1544 14295 RETURN
1545 14300 IF E6=A2 THEN IF I2=0 THEN 14325
1546 14305 GOSUB 875
1547 14310 REM G1=MOST RECENT TO: G2=T-G1
1548 14315 REM G3=BREAK BEING LOOKED FOR.
1549 14320 RETURN
1550 14325 IF T>4166.67 THEN GOSUB 875 ELSE GOSUB 850
1551 14330 RETURN
1552 C *****
1553 C *
1554 C * ROUTINES FOR BOTH TIME AND VOLTAGE THRESHOLDED CALCULATION. *
1555 C *
1556 C *****
1557 14335 REM BREAK NOT FOUND
1558 14340 IF T=8333.33 THEN T=8333.33
1559 14345 G2=T-G1
1560 14350 E7=E6
1561 14355 I3=I2
1562 14360 IF G1=1 THEN I2=FNI(G2,R1) ELSE I2=FNI(G2,R2)
1563 14365 IF G1=1 THEN E6=FNE(G2,R1,C1) ELSE E6=FNE(G2,R2,C1)
1564 14370 G4=SGN(I3)
1565 14375 G5=SGN(I2)
1566 14380 IF G4=-G5 OR G5=0 AND G4<0 THEN 14425
1567 14385 REM NO CHANGE IN SIGN OF I: NO BREAK.
1568 14390 A1=A1+1
1569 14395 T(V1,A1)=T
1570 14400 E(V1,A1)=E6
1571 14405 I(V1,A1)=I2

```

PITS-33

```

1572      14410 GOSUB 14715
1573      14415 IF T=8333.33 THEN 14435 ELSE RETURN
1574      14420 REM ESTABLISH DIODE COMMUTATION TIME
1575      14425 A=FNL(T(V1,A1),0,I3,T,0,I2)
1576      14430 A1=A1+1
1577      14435 T(V1,A1)=T=A4
1578      14440 G2=A4-G1
1579      14445 IF G1=1 THEN I2=FNI(G2,R1) ELSE I2=FNI(G2,R2)
1580      14450 IF ABS(I2)>.001 THEN 14455 ELSE 14480
1581      14455 A1=A1-1
1582      14460 GO TO 14425
1583      14465 REM BREAK FOUND: BREAK TIME IN S(V1,G3)
1584      14470 T=S(V1,G3)
1585      14475 G2=T-G1
1586      14480 I3=I2
1587      14485 E7=E6
1588      14490 IF G1=1 THEN I2=FNI(G2,R1) ELSE I2=FNI(G2,R2)
1589      14495 IF G1=1 THEN E6=FNE(G2,R1,C1) ELSE E6=FNE(G2,R2,C1)
1590      14500 A1=A1+1
1591      14505 T(V1,A1)=T
1592      14510 E(V1,A1)=E6
1593      14515 I(V1,A1)=I2
1594      14520 GOSUB 14715
1595      14525 A1=A1+1
1596      14530 T(V1,A1)=T
1597      14535 I(V1,A1)=I2
1598      14540 E(V1,A1)=0
1599      14545 CALL FNP(R1,L1,0)
1600      14550 G1=T
1601      14555 I3=I2
1602      14560 E7=0
1603      14565 CALL FNT(G1,I2,0,R1,L1,0)
1604      14570 T=T+T8
1605      14575 IF T=8333.33 THEN T=8333.33
1606      14580 G2=T-G1
1607      14585 A1=A1+1
1608      14590 I2=I(V1,A1)=FNI(G2,R1)
1609      14595 T(V1,A1)=T
1610      14600 E(V1,A1)=E6=0
1611      14605 GOSUB 14715
1612      14610 GOSUB 850
1613      14615 G3=G3+1
1614      14620 G1=T
1615      14625 IF T=8333.33 THEN 14635 ELSE RETURN
1616      14630 REM END OF HALF-CYCLE
1617      14635 R(V1,1)=A1
1618      14640 IF V1=1 AND V9<3 THEN R(V1,3)=-1 ELSE R(V1,3)=1
1619      14645 R(V1,6)=E6
1620      14650 R(V1,8)=I2
1621      14655 R(V1,9)=R(V1,9)/8333.33
1622      14660 IF G1>1 THEN GOSUB 850
1623      14665 IF G3=26 THEN S(V1,G3)=0
1624      14665 A9=1
1625      14670 RETURN
1626      14675 REM COMPUTE DIODE
1627      14680 G1=T
1628      14685 I(V1,A1)=I2=0

```

PITS-34

```
1429 14690 IF 01=1 THEN E6=FNE(G2,R1,C1) ELSE E6=FNE(G2,R2,C1)
1430 14695 E(V1,A1)=E6
1431 14700 GOSUB 14715
1432 14705 IF 01=1 THEN GOSUB 875 ELSE GOSUB 850
1433 14710 RETURN
1434 14715 R(V1,9)=R(V1,9)+((ABS(I3)+ABS(I2))/2)*(T-T(V1,A1-1))
1435 14720 RETURN
1436 14725 PRINT 'NO DATA IN HALF-CYCLE CHOSEN FOR INITIAL CONDITIONS.'
1437 14728 PRINT ' TRY AGAIN.'
1438 14730 GO TO 14033
```

PITS-35

```

1439 C *****
1440 C *
1441 C * VOLTAGE THRESHOLDING ROUTINE
1442 C *
1443 C * CHOICE OF 6 MANIFOLDS (DEFAULT=EQUIVALENT PATTERN)
1444 C *
1445 C * CHOICE OF HARDWARE OR NO-HARDWARE LIMIT
1446 C * (DEFAULT=HARDWARE LIMITED-NO BREAKS IN FIRST 140 US OR LAST 140
1447 C * US OF HALF-CYCLE, OR WITHIN 140 US OF PREVIOUS BREAK).
1448 C *
1449 C * CHOICE OF WELDING
1450 C * ALLOWS EARLY CLEARING OF VC TO START FRESH PATTERN (1) OR
1451 C * FIRING BASED ONLY ON THE MANIFOLD (2). DEFAULT=2
1452 C *
1453 C * TIME OF FIRST BREAK MAY BE ARBITRARILY SET.
1454 C * DEFAULT INPUT (0 OR -2) MEANS NO BREAK IS FORCED TO OCCUR
1455 C * EARLY IN THE HALF-CYCLE EXCEPT BY THE MANIFOLD OR WELDING
1456 C * CONTROL. NON-DEFAULT ENTRY LETS USER SPECIFY WHEN FIRST
1457 C * BREAK OCCURS.
1458 C *
1459 C * WELDING CONTROL CAN FORCE A FIRST BREAK TO OCCUR! 'TIME OF
1460 C * FIRST BREAK' INPUT CAN SPECIFY WHEN BUT CANNOT TURN WELDING
1461 C * CONTROL OFF.
1462 C *
1463 C *****
1464 16000 REM VOLTAGE THRESHOLDING
1465 16005 PRINT ' '
1466 16010 PRINT 'CHOOSE MANIFOLD: 1) TYPED IN VOLTAGES'
1467 16015 PRINT TAB(17);'2) EQUIVALENT PATTERN'
1468 16020 PRINT TAB(17);'3) RANDOM VOLTAGE PATTERN'
1469 16025 PRINT TAB(17);'4) SINUSOID PATTERN'
1470 16030 PRINT TAB(17);'5) RAMP PATTERN'
1471 16035 PRINT TAB(17);'6) TRAPEZOID OR OTHER USER SUPPLIED PATTERN'
1472 16040 PRINT 'CHOICE, DIGIT 1 THROUGH 6'
1473 16045 INPUT D2
1474 16050 IF D2=-2 THEN D2=2
1475 16055 IF D2<INT(D2) OR D2<1 OR D2>6 THEN 16040
1476 16060 PRINT ' '
1477 16065 ON D2 GO TO 16315,16070,16085,16140,16175,16220
1478 16070 PRINT 'BREAK VOLTAGE='
1479 16075 INPUT D3
1480 16080 IF D3=0 THEN 16310 ELSE 16070
1481 16085 IF D3=0 THEN 16120
1482 16090 PRINT 'RANDOMIZE'
1483 16095 INPUT V1
1484 16100 IF V1='YES' OR V1='Y' THEN 16105 ELSE 16115
1485 16105 RANDOMIZE
1486 16110 K8=1
1487 16115 K8=K8+1
1488 16120 D4=D5=0
1489 16125 PRINT 'PEAK ALLOWED BREAK VOLTAGE='
1490 16130 INPUT D3
1491 16135 IF D3=0 THEN 16310 ELSE 16125
1492 16140 PRINT 'PEAK ALLOWED BREAK VOLTAGE='
1493 16145 INPUT D3
1494 16150 IF D3=0 THEN 16155 ELSE 16140
1495 16155 PRINT 'PHASE ANGLE IN DEGREES='

```

PITS-36

```

1496      14140 INPUT D4
1497      14145 D4=148D4/360
1498      14170 GO TO 14310
1499      14175 PRINT 'RAMP VOLTAGE AT T=0 ='
1500      14180 INPUT D3
1501      14185 IF D3<0 THEN 14175
1502      14190 PRINT 'RAMP VOLTAGE AT T=8333.33 ='
1503      14195 INPUT D4
1504      14200 IF D4=0 THEN IF D3=0 THEN 14175
1505      14205 IF D4=0 THEN 14190
1506      14210 D4=(D4-D3)/8333.33
1507      14215 GO TO 14310
1508      14220 REM USER INPUT ROUTINE MAY RUN TO 14305
1509      14225 PRINT 'PLATEAU VOLTAGE='
1510      14230 INPUT D5
1511      14235 IF D5=0 THEN 14225
1512      14240 PRINT 'PLATEAU STARTS AT T='
1513      14245 INPUT D3
1514      14250 IF D3=-2 THEN 14295
1515      14255 IF D3<0 OR D3>8333.33 THEN 14240
1516      14260 PRINT 'PLATEAU ENDS AT T='
1517      14265 INPUT D4
1518      14270 IF D4=-2 THEN 14305
1519      14275 IF D4<0 OR D4>8333.33 THEN 14260
1520      14280 IF D4<D3 THEN D4=D3
1521      14285 D4=8333.33-D4
1522      14290 GO TO 14310
1523      14295 D3=D4-1000
1524      14300 GO TO 14310
1525      14305 IF D3<4166.67 THEN D4=D3 ELSE 14240
1526      14310 PRINT '
1527      14315 PRINT 'CONFORMITY CONTROL: 1) STRICT CONTROL'
1528      14320 PRINT TAB(20);'2) HARDWARE LIMITED CONTROL'
1529      14325 PRINT 'INPUT 1 OR 2'
1530      14330 INPUT D4
1531      14335 IF D4=-2 THEN D4=2
1532      14340 IF D4<>1 THEN IF D4<>2 THEN 14325
1533      14345 PRINT '
1534      14350 PRINT 'HELDING CONTROL: 1) FIRE DISCHARGE AT OR NEAR T=0'
1535      14355 PRINT TAB(17);'2) FIRE DISCHARGE BASED ONLY ON MANIFOLD'
1536      14360 PRINT 'INPUT 1 OR 2'
1537      14365 INPUT D8
1538      14370 IF D8=2 OR D8=-2 THEN D8=0
1539      14375 IF D8<0 THEN IF D8<>1 THEN 14360
1540      14380 PRINT '
1541      14385 PRINT 'FIRST BREAK CONTROL'
1542      14390 PRINT 'TIME AT WHICH FIRST BREAK MAY/WILL OCCUR='
1543      14395 INPUT D7
1544      14400 IF D7<0 THEN D7=0
1545      14405 IF D7<0 THEN IF D6=2 THEN 14420
1546      14410 IF D7=0 THEN IF D6=2 THEN IF D6=1 THEN D7=140
1547      14415 GO TO 14425
1548      14420 IF D7<140 THEN D7=140
1549      14425 IF D7=8333.33 THEN 14390
1550      14430 IF D8=1 THEN IF D6=1 THEN IF D7=0 THEN IF D7=0 THEN D8=0
1551      14435 PRINT '
1552      14440 PRINT 'SATISFIED WITH SETUP'

```

PITS-37

```

1753 16445 INPUT V16
1754 16450 IF V16<>'YES' THEN IF V16<>'Y' THEN IF V16<>'-2' THEN 16005
1755 16455 REM SETUP COMPLETED
1756 16460 IF D7=0 THEN 16495
1757 16465 IF D8=1 THEN 16480
1758 16470 GO TO 16530
1759 16475 REM CLEAR HISTORY
1760 16480 IF V9=1 THEN S(V1,G3)=T+.01 ELSE S(V1,G3)=.01
1761 16485 GOSUB 14465
1762 16490 GO TO 16530
1763 16495 T=T+.50
1764 16500 IF T=D7 THEN T=D7
1765 16505 IF T=D7 THEN 16520
1766 16510 GOSUB 14335
1767 16515 GO TO 16495
1768 16520 S(V1,G3)=T
1769 16525 GOSUB 14465
1770 C *****
1771 C *
1772 C * CHARGING CALCULATIONS, VOLTAGE THRESHOLDING.
1773 C *
1774 C *****
1775 16530 REM NORMAL THRESHOLDING ROUTINE--VOLTAGE
1776 16535 IF Q1=1 THEN H1=FNE(T-G1,K1,C1) ELSE H1=FNE(T-G1,R2,C1)
1777 16540 H2=FNR(T)
1778 16545 IF D2=1 THEN IF H2=0 THEN 16560
1779 16550 IF H1>H2 THEN D8=1 ELSE D8=0
1780 16555 IF H2=H1 THEN 16730
1781 16560 T=T+.50
1782 16565 IF G3>14 OR G3>25 THEN 16600
1783 16570 IF Q1=1 THEN H1=FNE(T-G1,R1,C1) ELSE H1=FNE(T-G1,R2,C1)
1784 16575 H2=FNR(T)
1785 16580 IF D2=1 THEN IF H2=0 THEN 16600
1786 16585 IF D8=0 THEN 16590 ELSE 16595
1787 16590 IF H1>H2 THEN 16610 ELSE 16598
1788 16595 IF H2=H1 THEN 16610
1789 16598 GO TO 16820
1790 16600 GOSUB 14335
1791 16605 IF A1=250 THEN IF K9<1 THEN 6045
1792 16605 IF K9<1 THEN 16560 ELSE RETURN
1793 16610 H5=T
1794 16615 H6=T(V1,A1)
1795 16620 IF Q1=1 THEN H3=FNE(H6-G1,R1,C1) ELSE H3=FNE(H6-G1,R2,C1)
1796 16622 H2=FNR(H5)
1797 16625 H4=FNR(H6)
1798 16627 IF Q1=1 THEN H1=FNE(H5-G1,R1,C1) ELSE H1=FNE(H5-G1,R2,C1)
1799 16630 H7=FNL(H6,H3,H4,H5,H1,H2)
1800 16635 H8=FNR(H7)
1801 16640 IF Q1=1 THEN H9=FNE(H7-G1,K1,C1) ELSE H9=FNE(H7-G1,R2,C1)
1802 16642 REM CHECK ITERATION CONVERGENCE
1803 16644 IF ABS(H9-H8)>.2 THEN 16645
1804 16646 IF D8=0 THEN IF H9>H8 THEN H5=H7 ELSE H6=H7
1805 16648 IF D8=1 THEN IF H9>H8 THEN H6=H7 ELSE H5=H7
1806 16650 IF H6=T(V1,A1) THEN H6=T(V1,A1)
1807 16652 IF H5>T THEN H5=T
1808 16654 IF H5=T THEN IF H6=T(V1,A1) THEN 16656 ELSE 16620 ELSE 16620
1809 16656 PRINT 'THRESHOLDING CONVERGENCE LOCKIN'. CALCULATION ABANDON.'

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FITS-38

```

1810 14658 GOSUB 14635
1811 14660 PRINT 'ON TO PRINT OUT RESULTS OR PLOT.'
1812 14662 RETURN
1813 14665 T=M7
1814 14670 IF T>8333.33 THEN 16600
1815 14675 IF G3=1 THEN 16685
1816 14680 IF T<S(V1,G3-1) THEN 16600
1817 14685 IF O1=1 THEN H6=FNI(T-G1,R1) ELSE H6=FNI(T-G1,R2)
1818 14690 IF O1=1 THEN IF H6<0 THEN 16885
1819 14695 IF O1=0 THEN IF H6<0 THEN 16885
1820 16700 IF D6=1 THEN 16730
1821 16705 REM CHECK FOR HARDWARE LIMITS TO BREAK TIME
1822 16710 IF 8333.33-T<200 THEN 16750
1823 16715 IF G3=1 THEN IF D6=2 THEN IF T<140 THEN 16775
1824 16715 IF G3=1 THEN 16730
1825 16720 IF T-S(V1,G3-1)<140 THEN 16775
1826 16725 REM TAKE A BREAK
1827 16730 S(V1,G3)=T
1828 16735 GOSUB 14465
1829 16740 D8=0
1830 16745 GO TO 16603
1831 16750 REM TERMINATE ON LATE BREAK INDICATION
1832 16755 GOSUB 14335
1833 16760 IF A9<1 THEN 16765 ELSE RETURN
1834 16765 T=8333.33
1835 16767 IF A1=250 THEN 6045
1836 16770 GO TO 16750
1837 16775 REM HARDWARE LIMITED, BREAK TIME
1838 16780 GOSUB 14335
1839 16785 IF K9=1 THEN RETURN
1840 16797 IF A1=250 THEN 6045
1841 16790 IF G3=1 THEN T=140.01 ELSE T=S(V1,G3-1)+140.01
1842 16795 IF O1=1 THEN H6=FNI(T-U1,R1) ELSE H6=FNI(T-G1,R2)
1843 16800 IF O1=1 THEN IF H6<0 THEN 16780
1844 16805 IF O1=0 THEN IF H6<0 THEN 16780
1845 16810 IF 8333.33-T<200 THEN 16750 ELSE 16730
1846 16815 REM COMMUTATION/BREAK CONFLICT RESOLUTION
1847 16820 IF O1=1 THEN B1=FNI(T-G1,R1) ELSE B1=FNI(T-G1,R2)
1848 16825 IF O1=1 THEN IF B1<0 THEN 16840
1849 16830 IF O1=0 THEN IF B1<0 THEN 16840
1850 16835 GO TO 16600
1851 16840 B2=FNI(T(V1,A1),0,I(V1,A1),T,0,B1)
1852 16845 IF O1=1 THEN B3=FNE(B2-G1,R1,C1) ELSE B3=FNE(B2-G1,R2,C1)
1853 16850 IF D8=0 THEN 16855 ELSE 16860
1854 16855 IF B3=FNR(B2) THEN 16865 ELSE 16600
1855 16860 IF B3=FNR(B2) THEN 16865 ELSE 16600
1856 16865 H2=FNR(B2)
1857 16870 T=B2
1858 16875 GO TO 16610
1859 16880 REM CHECK ORDER OF COMMUTATION/BREAK
1860 16885 B2=FNI(T(V1,A1),0,I(V1,A1),T,0,H6)
1861 16890 IF B2<T THEN 16600 ELSE 16700
1862 99999END

```

TABLE D.2. Memory Map of Program PITS.

Statements	Contents
1-200	Initial setup
500-999	Charging equation functions; utility routines
1000-1100	Core routine
2000-3200	Initialization routine
4000-4100	Calculation control routine
4300-5200	Voltage thresholding manifold functions
6000-6150	Time thresholding routine
8000-8999	Output control routine
9000-9999	PEPSUB
10000-10999	Miniplot
11000-11999	Printed output routine
12000-12100	Termination routine
14000-14330	Calculation setup
14335-14999	General charging calculation routine.
16000-16525	Voltage thresholding setup
16530-16999	Voltage thresholding calculation routine
-99999	End

V. Sample Run of Program PITS

On pages EX-1 through EX-11 appears the output of a short run of program PITS. This run was arranged to show syntax of as many options as possible, with secondary consideration given to the direct applicability of the data used to a laboratory situation. The interaction will be described page by page. PEPSUB output produced from the run is shown in Figure D.4 at the end of the sample run.

EX-1

URLG
 NACC 33.36 TTY U02038
 BRUN AS:41000-1393602639,45.00,100
 RUNID:Y05375 DATE:070878 TIME:141104
 PASSWORD PLEASE

 CONTINUE
 ELIB*BACKUP.BASIC CHEMISTRY*WALTERS.

BASIC X4.0.4 14:11:39 8 JUL 78

>OLD:PITS
 >RUNNH
 DO YOU WANT HARD COPY? NO
 WHAT IS POWER SUPPLY FREQUENCY--
 60 OR 0.1 HERTZ? 60

HOME? 1
 R(FORWARD BIASED)=? 40000
 R(REVERSE BIASED)=? 35E6
 L(HENRIES)=? 25
 C(MICROFARADS)=? .015
 PEAK XMR VOLTAGE=? 8274
 LENGTH OF DISCHARGE(MICROSECONDS)=? 40
 T0(START TIME FROM ZERO CROSSING)=? 0
 I0(MILLIAMPS)=? 0
 E0=? 6000
 MAXIMUM PREDICTED BREAKS PER HALF CYCLE=? 25
 FOR HOW MANY HALF-CYCLES DO YOU WISH TO ENTER BREAK TIMES? 1

ENTER BREAK TIMES IN MICROSECONDS FOR EACH HALF CYCLE.
 AFTER ALL BREAKS ENTERED FOR A HALF CYCLE, INPUT 0.

HALF CYCLE 1

ENTER BREAK TIMES FRESH OR ADD TO PREVIOUS LIST
 TYPE 'FRESH' OR 'ADD TO'? FRESH

BREAK TIME=? 1000
 BREAK TIME=? 5000
 BREAK TIME=? 0
 DO YOU WISH TO EDIT BREAK TIMES? N

ENTER BREAK VOLTAGES FOR HOW MANY HALF-CYCLES? 1

ENTER BREAK VOLTAGES IN VOLTS IN THE ORDER DESIRED.
 DEFAULT -3 GIVES 6000 VOLTS.
 IN FRESH MODE, AFTER LAST BREAK, ENTER ZERO.

HALF-CYCLE 1

FRESH OR EDIT? FRESH

EX-2

BREAK VOLTAGE=? 7000
 BREAK VOLTAGE=? 6000
 BREAK VOLTAGE=? 5000
 BREAK VOLTAGE=? 0

FRESH, INSERT, DELETE, LIST, OR DONE? LIST

HOME? NUMBER	1	BREAK VOLTAGE
1		7000
2		6000
3		5000

FRESH, INSERT, DELETE, LIST, OR DONE? DELETE
 WHICH BREAK? 2

FRESH, INSERT, DELETE, LIST, OR DONE? LIST

HOME? NUMBER	1	BREAK VOLTAGE
1		7000
2		5000

FRESH, INSERT, DELETE, LIST, OR DONE? INSERT
 INSERT AFTER WHICH BREAK? 1
 BREAK VOLTAGE=? 6000

FRESH, INSERT, DELETE, LIST, OR DONE? LIST

HOME? NUMBER	1	BREAK VOLTAGE
1		7000
2		6000
3		5000

FRESH, INSERT, DELETE, LIST, OR DONE? DONE

THE POSSIBLE ROUTINES ARE:
 INPUT, CALCULATE, OUTPUT, TERMINATE.
 ENTER A NUMBER 1, 2, 3, OR 4.? 1

WHAT INITIALIZATION OPTION DO YOU DESIRE? 4
 MAXIMUM PREDICTED BREAKS PER HALF CYCLE=? 25
 FOR HOW MANY HALF-CYCLES DO YOU WISH TO ENTER BREAK TIMES? 1

ENTER BREAK TIMES IN MICROSECONDS FOR EACH HALF CYCLE.
 AFTER ALL BREAKS ENTERED FOR A HALF CYCLE, INPUT 0.

HALF CYCLE 1

ENTER BREAK TIMES AFRESH OR ADD TO PREVIOUS LIST
 TYPE 'FRESH' OR 'ADD TO'? ADD TO

E1-3

BREAK TIME=? 3000
 BREAK TIME=? 0
 DO YOU WISH TO EDIT BREAK TIMES? YES

HOME? 1
 BREAK TIMES ARE:

1 1000
 2 3000
 3 5000

REMOVE WHICH BREAK? 2
 REMOVE WHICH BREAK? 0
 SATISFIED FOR THIS HALF CYCLE? Y

ENTER BREAK VOLTAGES FOR HOW MANY HALF-CYCLES? 0

THE POSSIBLE ROUTINES ARE:
 INPUT, CALCULATE, OUTPUT, TERMINATE.
 ENTER A NUMBER 1, 2, 3, OR 4.? 2

CHOOSE CALCULATION METHOD: 1) TIME THRESHOLDING
 2) VOLTAGE THRESHOLDING
 3) ABORT

CHOOSE 1, 2, OR 3? 3

THE POSSIBLE ROUTINES ARE:
 INPUT, CALCULATE, OUTPUT, TERMINATE.
 ENTER A NUMBER 1, 2, 3, OR 4.? 123

ENTER A NUMBER 1, 2, 3, OR 4.? 2

CHOOSE CALCULATION METHOD: 1) TIME THRESHOLDING
 2) VOLTAGE THRESHOLDING
 3) ABORT

CHOOSE 1, 2, OR 3? 1

WHICH HALF CYCLE DO YOU WISH TO USE? 1

BASE INITIAL CONDITIONS ON 1) TYPED IN INPUT
 2) PRIOR RESULT IN THIS HALF-CYCLE OR
 3) RESULT OF PREVIOUS HALF-CYCLE.

CHOOSE 1, 2, OR 3? 1

USE TIMES FROM THIS HALF-CYCLE OR PREVIOUS HALF-CYCLE.
 INPUT 'THIS' OR 'PREVIOUS'? THIS

THE POSSIBLE ROUTINES ARE:
 INPUT, CALCULATE, OUTPUT, TERMINATE.
 ENTER A NUMBER 1, 2, 3, OR 4.? 2

EX-4

CHOOSE CALCULATION METHOD: 1) TIME THRESHOLDING
2) VOLTAGE THRESHOLDING
3) ABORT

CHOOSE 1, 2, OR 3? 1

WHICH HALF CYCLE DO YOU WISH TO USE? 2

BASE INITIAL CONDITIONS ON 1) TYPED IN INPUT
2) PRIOR RESULT IN THIS HALF-CYCLE OR
3) RESULT OF PREVIOUS HALF-CYCLE.

CHOOSE 1, 2, OR 3? 3

USE TIMES FROM THIS HALF-CYCLE OR PREVIOUS HALF-CYCLE.
INPUT 'THIS' OR 'PREVIOUS'? PREVIOUS

THE POSSIBLE ROUTINES ARE:
INPUT, CALCULATE, OUTPUT, TERMINATE.
ENTER A NUMBER 1, 2, 3, OR 4.? 3

WHAT OUTPUT OPTION DO YOU WANT? 20

HOW MANY HALF CYCLES ARE TO BE OUTPUT? 2

INPUT TITLE. '-2' GIVES DEFAULT.
? TIME THRESHOLDING SAMPLE

CHOOSE PLOT VARIABLES.
ANSWER 'YES' OR 'Y' FOR EACH PLOTTED VARIABLE DESIRED.

CAPACITOR VOLTAGE? Y
CHARGING CURRENT? Y
XMR VOLTAGE? Y

ENTER SCALING OPTION? 2

IF SATISFIED WITH PLOT SETUP, ENTER 'YES' OR 'Y'
OTHERWISE, YOU CAN GO BACK AND TRY AGAIN.
ENTERING 'ABORT' TERMINATES THIS PASS OF OUTPUT.
SATISFIED? Y
A) ENABLE HARD COPY PLOTTING? YES

THE POSSIBLE ROUTINES ARE:
INPUT, CALCULATE, OUTPUT, TERMINATE.
ENTER A NUMBER 1, 2, 3, OR 4.? 3

WHAT OUTPUT OPTION DO YOU WANT? 2

HOW MANY HALF CYCLES ARE TO BE OUTPUT? 2

INPUT TITLE. '-2' GIVES DEFAULT.
? TIME THRESHOLDING SAMPLE

EX-5

HOME? 1

TIME THRESHOLDING SAMPLE

HALF-CYCLE 1

BREAK VALUES

BREAK	VOLTAGE	CURRENT	TIME
1	5992	-.08	1000.0
2	8602	-.02	5000.0

HOME? 1

HALF-CYCLE 2

BREAK VALUES

BREAK	VOLTAGE	CURRENT	TIME
1	7238	-.12	1000.0
2	8602	-.02	5000.0

HOME? 1

TIME THRESHOLDING SAMPLE

HALF-CYCLE 1

PARAMETER DUMP

R(FORWARD)= .40E+05	R(REV. BIAS)= .35E+08	C(UF)= .0150
L(HENRIES)= 25.000	GAMMA(DEG)= -76.56	N BREAKS= 2
Z0= .17213E+06	S**2= -.50667E+10	S= .7118E+05
E(XMFR)= 8274	DISCHARGE DURATION= 40	
I0 AT START = 0		
I0 AT END = -.20703515		
E0 AT START = 6000		
E0 AT END = 7248.4695		
AVG. I(MA) = 28.62737		

HOME?

EX-6

1

HALF-CYCLE 2

PARAMETER DUMP

R(FORWARD)= .40E+05	R(REV. BIAS)= .35E+08	C(UF)= .0150
L(HENRIES)= 25.000	GAMMA(DEG)= -76.56	N BREAKS= 2
Z0= .17213E+06	S**2= -.50667E+10	S= .7118E+05
E(XHFR)= 9274	DISCHARGE DURATION= 40	
I0 AT START = -.20703515		
I0 AT END = -.20703515		
E0 AT START = 7248.4695		
E0 AT END = 7248.4695		
AVG. I(MA) = 28.632328		

THE POSSIBLE ROUTINES ARE:
 INPUT, CALCULATE, OUTPUT, TERMINATE.
 ENTER A NUMBER 1, 2, 3, OR 4? 2

CHOOSE CALCULATION METHOD: 1) TIME THRESHOLDING
 2) VOLTAGE THRESHOLDING
 3) ABORT

CHOOSE 1, 2, OR 3? 2

WHICH HALF CYCLE DO YOU WISH TO USE? 1

BASE INITIAL CONDITIONS ON 1) TYPED IN INPUT
 2) PRIOR RESULT IN THIS HALF-CYCLE OR
 3) RESULT OF PREVIOUS HALF-CYCLE.

CHOOSE 1, 2, OR 3? 1

CHOOSE MANIFOLD: 1) TYPED IN VOLTAGES
 2) EQUIVALENT PATTERN
 3) RANDOM VOLTAGE PATTERN
 4) SINUSOID PATTERN
 5) RAMP PATTERN
 6) TRAPEZOID OR OTHER USER SUPPLIED PATTERN

CHOICE, DIGIT 1 THROUGH 6? 1

CONFORMITY CONTROL: 1) STRICT CONTROL
 2) HARDWARE LIMITED CONTROL

INPUT 1 OR 2? 2

MELDING CONTROL: 1) FIRE DISCHARGE AT OR NEAR T=0
 2) FIRE DISCHARGE BASED ONLY ON MANIFOLD

INPUT 1 OR 2? 2

FIRST BREAK CONTROL
 TIME AT WHICH FIRST BREAK MAY/WILL OCCUR=? 0

SATISFIED WITH SETUP? Y

EX-7

THE POSSIBLE ROUTINES ARE:
INPUT, CALCULATE, OUTPUT, TERMINATE.
ENTER A NUMBER 1, 2, 3, OR 4.? 3

WHAT OUTPUT OPTION DO YOU WANT? 1

HOW MANY HALF CYCLES ARE TO BE OUTPUT? 1

INPUT TITLE. '-2' GIVES DEFAULT.
? VOLTAGE THRESHOLDING SAMPLE

HOME? 1

EX-6

VOLTAGE THRESHOLDING SAMPLE

HALF-CYCLE 1

T	E	I	T	E	I	T	E	I
0.0	0	0.00	2897.3	6252	13.22	5571.9	3340	129.84
0.0	4000	0.00	2947.3	6197	14.33	5621.9	3947	126.30
50.0	3999	-1.17	2997.3	6347	15.40	5671.9	4381	122.05
100.0	3999	-1.16	3047.3	6400	16.41	5721.9	4780	117.18
150.0	3998	-1.16	3097.3	6456	17.36	5771.9	5162	111.77
200.0	3998	-1.15	3147.3	6516	18.25	5821.9	5535	105.89
250.0	3997	-1.15	3197.3	6578	19.06	5871.9	5867	99.61
300.0	3997	-1.14	3247.3	6643	19.79	5921.9	6180	93.00
350.0	3996	-1.14	3297.3	6710	20.45	5971.9	6487	86.11
400.0	3996	-1.14	3347.3	6779	21.02	6021.9	6762	79.01
450.0	3995	-1.13	3397.3	6850	21.50	6071.9	7014	71.74
500.0	3995	-1.13	3447.3	6922	21.89	6121.9	7241	64.41
550.0	3995	-1.12	3497.3	6996	22.19	6171.9	7443	57.02
600.0	3994	-1.12	3500.3	7000	22.21	6221.9	7621	49.62
650.0	3994	-1.11	3500.3	0	22.21	6271.9	7774	42.26
700.0	3993	-1.11	3540.3	0	33.28	6321.9	7902	34.98
750.0	3993	-1.11	3590.3	133	46.09	6371.9	8007	27.82
800.0	3993	-1.10	3640.3	306	57.69	6421.9	8088	20.81
850.0	3992	-1.10	3690.3	516	68.09	6471.9	8146	13.99
900.0	3992	-1.09	3740.3	759	77.31	6521.9	8182	7.37
950.0	3992	-1.09	3790.3	1030	85.37	6571.9	8195	.97
1000.0	3992	-1.08	3840.3	1326	92.30	6579.7	8196	0.00
1050.0	3991	-1.08	3890.3	1644	98.15	6629.7	8195	-1.09
1100.0	3991	-1.08	3940.3	1980	102.95	6679.7	8195	-1.10
1150.0	3991	-1.07	3990.3	2329	106.75	6729.7	8195	-1.10
1200.0	3991	-1.07	4040.3	2690	109.59	6779.7	8194	-1.10
1250.0	3990	-1.06	4090.3	3059	111.53	6829.7	8194	-1.11
1300.0	3990	-1.06	4140.3	3433	112.61	6879.7	8194	-1.11
1350.0	3990	-1.06	4190.3	3809	112.89	6929.7	8193	-1.11
1400.0	3990	-1.05	4240.3	4185	112.43	6979.7	8193	-1.12
1450.0	3990	-1.05	4290.3	4558	111.27	7029.7	8192	-1.12
1500.0	3989	-1.04	4340.3	4926	109.47	7079.7	8192	-1.13
1550.0	3989	-1.04	4390.3	5287	107.09	7129.7	8192	-1.13
1600.0	3989	-1.04	4440.3	5639	104.19	7179.7	8191	-1.13
1650.0	3989	-1.03	4490.3	5981	100.81	7229.7	8191	-1.14
1700.0	3989	-1.03	4493.1	6000	100.60	7279.7	8190	-1.14
1750.0	3989	-1.03	4493.1	0	100.60	7329.7	8190	-1.15
1800.0	3989	-1.02	4533.1	0	107.08	7379.7	8189	-1.15
1850.0	3989	-1.02	4583.1	369	114.22	7429.7	8189	-1.15
1900.0	3989	-1.02	4633.1	760	120.03	7479.7	8188	-1.16
1950.0	3989	-1.01	4683.1	1168	124.58	7529.7	8188	-1.16
2000.0	3989	-1.01	4733.1	1589	127.92	7579.7	8187	-1.17
2050.0	3988	-1.01	4783.1	2020	130.12	7629.7	8187	-1.17
2100.0	3988	-1.00	4833.1	2455	131.25	7679.7	8186	-1.18
2147.3	3988	0.00	4883.1	2893	131.38	7729.7	8185	-1.18
2197.3	3989	.11	4933.1	3330	130.58	7779.7	8185	-1.18
2247.3	3989	.41	4983.1	3763	128.91	7829.7	8184	-1.19
2297.3	3991	.88	5033.1	4189	126.46	7879.7	8184	-1.19
2347.3	3995	1.51	5083.1	4605	123.29	7929.7	8183	-1.20
2397.3	4002	2.26	5131.9	5000	119.58	7979.7	8182	-1.20
2447.3	4011	3.13	5181.9	0	119.58	8029.7	8182	-1.21
2497.3	4023	4.10	5171.9	0	124.12	8079.7	8181	-1.21
2547.3	4038	5.14	5221.9	422	128.00	8129.7	8180	-1.22
2597.3	4057	6.24	5271.9	850	132.34	8179.7	8179	-1.22
2647.3	4080	7.38	5321.9	1303	134.57	8229.7	8179	-1.22
2697.3	4106	8.55	5371.9	1754	135.63	8279.7	8178	-1.23
2747.3	4137	9.73	5421.9	2206	135.62	8329.7	8177	-1.23
2797.3	4171	10.91	5471.9	2657	134.59	8379.7	8177	-1.23
2847.3	4209	12.08	5521.9	3102	132.65			

EX-9

VOLTAGE THRESHOLDING SAMPLE

HALF-CYCLE 1

PARAMETER DUMP

R(FORWARD)= .40E+05	R(REV. BIAS)= .35E+08	C(UF)= .0150
L(HENRIES)= 25.000	GAMMA(DEG)= -76.56	N BREAKS= 3
Z0= .17213E+06	S**2= -.50667E+10	S= .7118E+05
E(XMFR)= 8274	DISCHARGE DURATION= 40	
IO AT START = 0		
IO AT END = -.23356816		
EO AT START = 6000		
EO AT END = 8177.1235		
AUG. I(MA) = 37.622839		

THE POSSIBLE ROUTINES ARE:
 INPUT, CALCULATE, OUTPUT, TERMINATE.
 ENTER A NUMBER 1, 2, 3, OR 4.? 3

WHAT OUTPUT OPTION DO YOU WANT? 10

HOW MANY HALF CYCLES ARE TO BE OUTPUT? 1

INPUT TITLE. '-2' GIVES DEFAULT.
 ? VOLTAGE THRESHOLDING SAMPLE

CHOOSE PLOT VARIABLES.
 ANSWER 'YES' OR 'Y' FOR EACH PLOTTED VARIABLE DESIRED.

CAPACITOR VOLTAGE? Y
 CHARGING CURRENT? N
 XMFR VOLTAGE? N

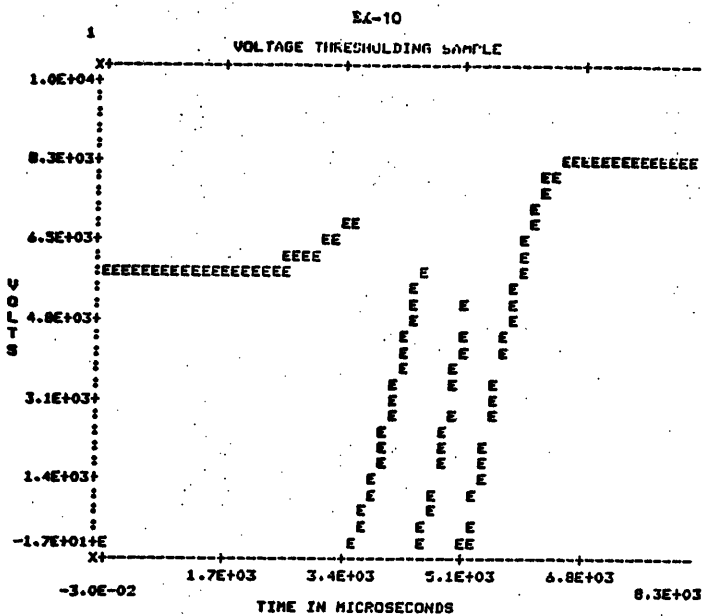
ENTER SCALING OPTION? 3

FULL SCALE VOLTAGE=? 10000

IF SATISFIED WITH PLOT SETUP, ENTER 'YES' OR 'Y'
 OTHERWISE, YOU CAN GO BACK AND TRY AGAIN.
 ENTERING 'ABORT' TERMINATES THIS PASS OF OUTPUT.
 SATISFIED? Y

HONE?

ess).



NORMAL RETURN

THE POSSIBLE ROUTINES ARE:
INPUT, CALCULATE, OUTPUT, TERMINATE.
ENTER A NUMBER 1, 2, 3, OR 4. ? 3

WHAT OUTPUT OPTION DO YOU WANT? 20

HOW MANY HALF CYCLES ARE TO BE OUTPUT? 1

INPUT TITLE. '-2' GIVES DEFAULT.
? VOLTAGE THRESHOLDING SAMPLE

CHOOSE PLOT VARIABLES.
ANSWER 'YES' OR 'Y' FOR EACH PLOTTED VARIABLE DESIRED.

CAPACITOR VOLTAGE? Y
CHARGING CURRENT? Y
XNFR VOLTAGE? Y

ENTER SCALING OPTION? 3

EX-11

FULL SCALE VOLTAGE=? 10000
FULL SCALE CURRENT=? 250

IF SATISFIED WITH PLOT SETUP, ENTER 'YES' OR 'Y'
OTHERWISE, YOU CAN GO BACK AND TRY AGAIN.
ENTERING 'ABORT' TERMINATES THIS PASS OF OUTPUT.
SATISFIED? Y

THE POSSIBLE ROUTINES ARE:
INPUT, CALCULATE, OUTPUT, TERMINATE.
ENTER A NUMBER 1, 2, 3, OR 4.? 4

TERMINATE OR KEEP RUNNING? TERMINATE
DO YOU WISH TO VIEW PLOT NOW OR
DO YOU WISH TO STORE SAME FOR LATER?
INPUT 'NOW' OR 'LATER'; DEFAULT= NOW? LSTER
DO YOU WISH TO VIEW PLOT NOW OR
DO YOU WISH TO STORE SAME FOR LATER?
INPUT 'NOW' OR 'LATER'; DEFAULT= NOW? LATER

FILE HAS BEEN CLOSED
NO EXIT FROM BASIC
THIS SHOULD BE THE LAST RETURN FROM THE PEP SUBROUTINE
THANK YOU FOR YOUR PATRONAGE.

TIME : 13.566

>BYE

UNIVAC BASIC 14:32:58 8 JUL 78
\$FIN/C

RUNID: Y05375 PROJECT: 41000

USER: 1893602639

ITEM	AMOUNT	COST
CPU TIME	0:00:12.287	\$0.43
FILE I/O REQUEST	148	\$0.07
FILE I/O WORDS	40355	\$0.01
SWAP REQUESTS	1	\$0.00
SWAP WORDS	19456	\$0.00
MEMORY USAGE	0.255	\$0.34
CARDS IN	1409	\$0.14
PAGES PRINTED	10	\$0.10
CONNECT MINUTES	22	\$0.18
SOFTWARE SUPPORT	29	\$0.40
JOB CHARGE	1	\$0.05
TOTAL COST		\$1.72

BASED ON RATES FOR EVENING RUNS
USER BALANCE \$168.27

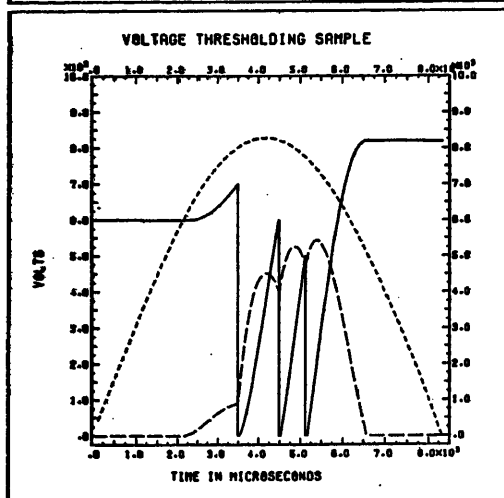
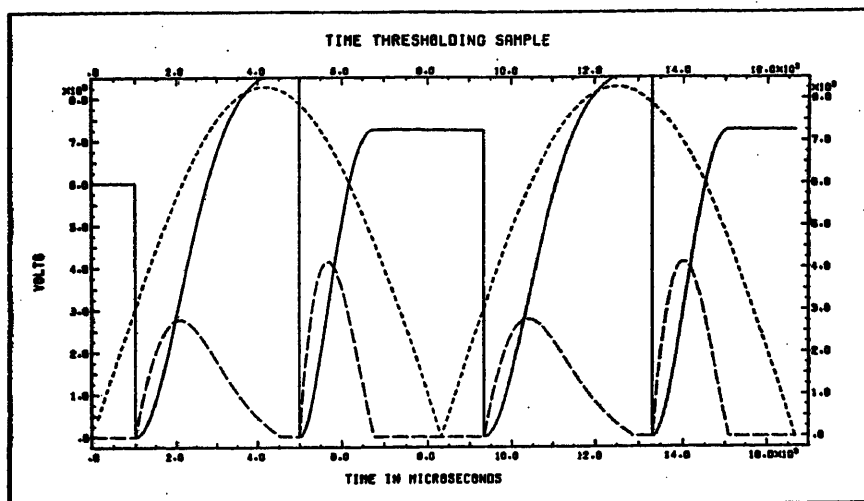
INITIATION TIME: 14:11:03 JUL 8, 1978

TERMINATION TIME: 14:33:06 JUL 8, 1978

Figure D.4

Plot Output of Sample PITS Run





↑ A
→ B

— V_C
- - V_T
· · I

EX-1. The first line, UWLG, is the log-on command from a DECwriter, the teletype-like device used for the sample run. Were the run made from a PEP terminal, the correct entry would be UWGT. The next line ("MACC 33.36 ... ") is the computer's response to UWLG. The @RUN statement starts the computer run (as opposed to being connected to the 1110's front end hardware which was accomplished above). The items given in the RUN statement are: user's initials, user's project number, user's I.D. number, job cost limit, and "output print page" limit. The cost and print limits shown are typical of those appropriate to a one hour run at evening rates (0.6 of daytime cost). After the RUN statement is entered, the computer responds with RUNID, the run's identification number, plus date and time information. The RUNID should be recorded as it is needed to obtain plot and hard copy print output from the computing center. A PASSWORD is then entered, as described fully in the Abel Inversion program documentation.

The BASIC interpreter is then called. The version accessed here (4.0.4) is an old version no longer supported by UNIVAC, but is the only version capable of running programs containing loops within subroutines which in turn are called from within loops. At some time, it should be possible to call BASIC by saying

@BASIC CHEMISTRY*WALTERS.

rather than what is entered in this sample. No firm date for this is yet known, however.

Once in BASIC, PITS is called up using the OLD:PITS command, and the RUNNH command starts execution. No hard copy print is to be obtained, as hard copy is already being produced on the DECwriter, making line-printer output superfluous. Line frequency (60 Hz) operation is chosen. The paper was not advanced when the opportunity was given with the "HOME?" question.

The rest of the page shows initialization occurring. In the first contiguous block of input (between the "HOME?" line and the next blank line), input was given which configured the software source as follows: forward resistance, 40 kilohms. Reverse biased resistance: 35 megohms. Inductance: 25 henries. Capacitance: 0.015 microfarads. Peak transformer voltage: 8274 volts. Discharge duration: 40 microseconds (using the "rule of thumb" discussed in Chapter III, this corresponds to a hardware spark source discharge duration of 80 microseconds). Initial current and time were both set to 0, and initial capacitor voltage was set to 6000 volts. Up to 25 breaks per half-cycle are calculable, and one half-cycle of break times is to be input.

There follows a group of instructions pertinent to inputting times for time thresholding. "Fresh" input is chosen, although on the first run through the initialization routine, there is no prior list of break times so that either "Fresh" or "Add to" input

s).

would function the same. The break times input are 1000 and 5000 microseconds after the start of the half-cycle, and the end of break time input is specified by entering a break time of zero. Break times are not edited on this call.

Break voltages are entered for only one half-cycle as well. The last few lines on page EX-1 give some instruction on the entering of break voltages and specify that "Fresh" input is to be made.

EX-2. A three break pattern is input, with the break voltage being 7000, 6000, and 5000 volts. The rest of the top two-thirds of the page shown an example of use of the editing capabilities of the voltage input routine. The second break is deleted, then reinserted, using listing after each operation to show the status of the break voltage list. After the choice "Done" is made, initialization is completed and the core control routine is accessed.

The nature of the four possible routines which may be accessed from the core routine are largely self-explanatory. "Input" is used to access the initialization routine again. The only initialization questions which are not re-asked are those concerning hard-copy printed output and line frequency. Options are provided (as given in the listing), for accessing selected portions or all of the other initialization questions.

ss).

In the example, the first call from the core routine is to the initialization routine, for the purpose of demonstrating the editing capabilities of the time thresholding routine. The "1" input to the core routine specifies that initialization is desired. Initialization option 4 is chosen; only the maximum number of breaks per half-cycle, break times, and break voltages will be requested by the routine with this option.

Again 25 maximum breaks per half-cycle are specified, and only one half-cycle of break times will be input. "Add to" input is specified so that the times typed in on page EX-1 may be edited.

EX-3. An additional break at 3000 microseconds is added to the old break time list, then deleted again. No further input concerning break voltages is given on this initialization call.

The core routine is then used to call the calculation routine ("2"). On the first call, calculation method "abort" ("3") is chosen, and control returns to the core routine. This gives the user a safety valve for getting out of the calculation routine after he inadvertently gets in. On the next attempted call, routine 123 is specified. Because this is not one of the possible routines, fresh input is solicited. The calculational routine is again called, and this time, time thresholded calculation is specified. Initial conditions are taken as those typed in during initialization (at this point there is not information anywhere

ss).

else to provide another legitimate answer. The program does check to ensure that some initial conditions are present.).

Calculations are performed on half-cycle one, and times at which breaks are to occur are taken from "this" half-cycle, i.e. the times typed in during initialization for half-cycle one. Once "this" is entered, the calculation is completed without user input, and the control routine comes on line again. At the bottom of the page, the calculation routine is recalled.

EX-4. Again time thresholding is used in the calculation. This pass, however, half-cycle two will be affected by the calculations. Initial conditions are based on the results of calculations of the previous half-cycle, i.e. the calculation just performed on half-cycle one. Thus half-cycles one and two will form a contiguous, melded patterned interval. Times are also taken from the "previous" half-cycle, so that the break times in half-cycle two will be identical to those in half-cycle one.

The output routine is then called. This pass through the output routine is an example of the problems which can arise when printed output is not obtained before plotting is attempted. PEPSUB output only is specified, both half-cycles on which computation has been performed are output, and the title on the plot is "Time Thresholding Sample". All three quantities (capacitor voltage, charging current, and transformer voltage) are to be plotted.

Next the scaling option is specified. As no information has yet been printed, scaling option 3 (user chosen) is impractical. Since the peak transformer voltage was 8274 volts, the default scaling (15 kV full scale) would be inappropriate. Scaling based on the maximum datum would give a plot with a scale of unknown (as yet) and perhaps strange grid spacing. So scaling option 2 is chosen, with the peak transformer voltage used as full scale. Satisfaction with the setup is indicated, and hard copy plotting is enabled. In a subsequent run, the plot just set up was obtained, and is shown in Figure D.4, inset A. It happened that capacitor voltage exceeded the peak transformer voltage in several places, which obscures a good deal of information including the break voltages on the plot. Had printed output been obtained first, before a plot was attempted, this difficulty would have been seen and compensated for by using some other input option.

Meanwhile the next step in the example is to attempt to recover some useful information about the time thresholded calculations (after all, the calculations worked correctly; just the output did not meet expectations). This time, output option 2 is chosen, so that break voltages will be given in addition to a parameter dump. Both half-cycles will be output, and the same title will be used.

EX-5. This page shows break data for the two half-cycles and the "parameter dump" for the first half-cycle. Comparing half-cycles one and two, it can be seen that the break voltage is the same for the second break of each half-cycle, but different for the first break. Thus initial conditions as typed in were not steady-state conditions for this pattern. From the break currents, it can be seen that the diode bridge was reverse biased for both breaks.

The parameter dump tabulates hardware parameters and the number of breaks obtained in the first three lines. Z_0 , s^2 , and $\sqrt{s^2}$ are listed across the third line. The fourth line gives peak transformer voltage and discharge duration in microseconds. Next are tabulations comparing charging current and charging voltage at the beginning and end of the half-cycle. When these are the same, a stable situation is indicated and, if iteration is being performed, that iteration is complete. Here, half-cycle one is not a stable situation. Finally, the average current for the half-cycle is printed, and may be used for average current effect corrections if desired.

EX-6. Half-cycle two parameter dump is at the top of the page. Comparing voltage and current at the start and end of the half-cycle indicates that a stable pattern has been computed and, if time thresholding were to be continued, the break voltages calculated for half-cycle two would continue to be calculated.

Next, voltage thresholding will be performed on half-cycle one. Recall that the typed in break voltages are still present, but that this voltage thresholding calculation will overwrite the typed in times. Initial conditions are taken as those which were typed in. The manifold chosen is "1", the typed in voltages. Hardware limited control and no break except by dint of crossing the manifold thresholds is also specified (both melting control and first break control are turned off). Satisfaction with the set-up is expressed, and the calculation occurs.

EX-7. A full print of the voltage thresholded charging curve is set up using output option 1.

EX-8. Here is a full charging curve for the voltage thresholded calculation. Some of the information which may be gleaned from this tabulation is:

- (1) The diode bridge is initially reverse biased.
- (2) The bridge becomes forward biased at 2147.3 μ s.
- (3) Breaks occur at 3500.3 μ s, 4493.1 μ s, and 5131.9 μ s.
- (4) Peak charging current is 135.63 mA at 5371.9 μ s.
- (5) The diode bridge reverse biases again at 6579.7 μ s.

This is also the time at which capacitor voltage peaks:
8196 V.

EX-9. A parameter dump associated with the tabulated printout on page EX-8 is given. Convergence of the charging

algorithm has not occurred. (Neither voltage nor current are the same at the beginning and end of the half-cycle.)

The remainder of the page sets up a MINIPLOT plot to view the voltage thresholded calculation result. Note how full scale voltage was specified (10000 volts).

EX-10. Here is the MINIPLOT output, showing the voltage charging curve. This is a rough plot, but indicates that 10 kV full scale is adequate for seeing charging information. PEPSUB can now be called with confidence, to get a high quality plot.

A PEPSUB call is executed at the bottom of page EX-10, and all plottable quantities will be put onto the plot.

EX-11. Full scale plot voltage is specified as 10000 volts, and full scale current is given as 250 milliamps.

The termination routine is called, and the decision to terminate confirmed. After a first attempt contained a typographical error, it is specified that plot is to be obtained "later" (at a separate run at a PEP terminal rather than at the DECwriter which has no plot capabilities). The run is then terminated, using BYE and @FIN,C. Several points concerning cost are shown in the tailsheet:

- (1) CPU time is mainly taken up in initial interpretation of the program, not in continued running. One long run with many reinitializations is less costly than many short runs.

- (2) Cards In represents user interaction with the program.
- (3) The sample run took 22 minutes.
- (4) Billing has been changed since the Abel Inversion routine was documented; use of BASIC is now billed through a Software Support charge. CPU costs have been reduced, however, so that total run cost should not be adversely affected.
- (5) This run was done at evening rates, which gives a saving of 40% compared to daytime rates. The same run would have cost \$2.87 during the day.

A separate run was used to obtain plotted output as shown in Figure D.4. Inset A shows some information about the time thresholded computations done but does not show all voltage data due to the scaling option chosen. Inset B of the voltage thresholded data shows a properly constructed plot of all the information in the tabulation on page EX-8.

VI. Variable List

Tabulated below are most of the variables used in program PITS. All variables not tabulated are used only as loop indices.

<u>Variable</u>	<u>Usage or Meaning</u>
A	Parameter in call to functions FNC and FNS.
A1	Number of points computed during a calculation. Also used as print output scratch variable.

is).

Variable	Usage or Meaning
A2	Instantaneous transformer voltage. Output scratch variable.
A3	Used as scratch variable for break time input and as and output scratch variable.
A4	Interpolated time of diode commutation (time thresholding routine). Scratch variable, number of break times entered during initialization. Also output scratch variable.
A6	Auxiliary variable for sorting input break times. In calculation routines,
	$A6 = (V_p/Z_0) \cos(\theta - (\theta_0 + \gamma)) .$
A7	$\theta/2X_L$; also used as X_C .
A8	$\cos(\theta_0 + \gamma)$; FNC(A7).
A9	$\sin(\theta_0 + \gamma)$; FNS(A7), also a point counter in the output routine.
A\$	Scratch input variable.
B1-B9	Intermediate storage for printed output.
B2	Interpolated diode commutation time (voltage thresholding routine).
B3	Capacitor voltage at time B2.
B\$(10)	Labels for initialization inputs.
C	Parameter taken to mean capacitance in calls to functions FNT, FNP, and FNE.
C1	Source capacitance.
D1	Calculation thresholding method.
D2	Number of manifold to be used.

Variable	Usage or Meaning
D3	Equivalent pattern: break voltage Random pattern: maximum break voltage Sine pattern: peak voltage Ramp pattern: intercept Trapezoid pattern: time at which plateau starts.
D4	Random pattern: number of break being sought Sine pattern: phase Ramp pattern: slope Trapezoid pattern: time at which plateau ends.
D5	Random pattern: voltage of break being sought Trapezoid pattern: plateau voltage.
D6	Conformity control.
D7	First break control.
D8	Melding control.
E	FNT parameter (voltage).
E(4,250)	Calculated charging voltage curves (capacitor voltage).
E1,E2	Peak transformer voltage. Two variables were originally provided in anticipation of some servo mechanism for varying transformer voltage to get stable voltage thresholding without user intervention. Option never designed.
E3	Maximum allowed input transformer voltage. Set to 32 kilovolts.
E5	Typed in initial voltage.
E6	Most recently computed capacitor voltage.
E7	Next most recently computed capacitor voltage.
F(3)	Flags. F(1):Hard copy option flag. F(2):MINIPLLOT output enable flag. F(3):unused.
G1	$t_0 (= \theta_0/2\pi)$.

Variable	Usage or Meaning
G2	$t - t_0 (= \theta/2\pi)$.
G3	Number of the break being sought.
G4	Half-cycle to be used as source of break times (used with "this" or "previous" input). Also: Sign of I3.
G5	Sign of I2. Also a loop index.

(Note: H variables appear only in the voltage thresholding routine.)

H1	Capacitor voltage at time = T.
H2	Manifold voltage at time = T.
H3	Capacitor voltage at time = H6.
H4	Manifold voltage at time = H6.
H5	Same as T.
H6	Most recent time used for computation before time T.
H7	Interpolated threshold crossing time.
H8	Manifold at time H7.
H9	Capacitor voltage at time H7.
I	Parameter in FNT call, used as initial current.
I1	Typed in initial current.
I2	Most recently computed current.
I3	Next most recently computed current.
I4	2π .
I5	$2\pi f$ (f is line frequency).
I6	Maximum allowed breaks per half-cycle.

I(4,250) Calculated charging current curves.

Variable	Usage or Meaning
J and K variables	Loop indices.
K8	Number of random numbers used.
K9	Flag indicating half-cycle completion.
L	Parameter in FNP and FNT function calls meaning inductance.
L1	Source inductance.
Q1	Flag indicating diode bias condition.
R	Parameter in FNT, FNP, FNI, and FNE indicating resistance.
R1	Forward biased source resistance.
R2	Reverse biased source resistance.
R(4,9)	Parameter storage. Specific meanings: R(n,1) Number of data points calculated in half-cycle n. R(n,2) Number of breaks in half-cycle n. R(n,3) Is there calculated data in this half-cycle? R(n,4) Cycle number in patterned interval. R(n,5) Capacitor voltage, start of half-cycle. R(n,6) Capacitor voltage, end of half-cycle. R(n,7) Charging current, start of half-cycle. R(n,8) Charging current, end of half-cycle. R(n,9) Average current during half-cycle n.
S1	s^2 .
S2	$\sqrt{ s^2 }$.
S3	Z_0 .
S4	γ (radians).
S5	V_p/Z_0 .
S6	S2-R1 or S2-R2, depending on which resistance is in use.
S(4,25)	Array of break times, either typed in or computed.

Variable	Usage or Meaning
T	Parameter in function calls to FNT, FNE, and FNI meaning time, in some cases referenced to the beginning of the half-cycle, in others referenced to the most recent t_0 .
T	Computed time: $(\theta + \theta_0)/2\pi$.
T1	θ_0 .
T2	$\theta_0 + \gamma$.
T3	Coefficient of csinhd function in voltage calculation. $T3 = \frac{V_D}{Z_0} (X_L \cos(T2) - R_{tot} \sin(T2)) - (X_L I_0 + \frac{R_{tot}}{X_C} E_0) .$
T4	Coefficient of ccosh function in voltage calculation. $T4 = \frac{V_0}{X_C} + \frac{V_D}{Z_0} \sin(T2) .$
T5	Coefficient of csinhd function in current calculation. $T5 = \frac{V_D}{Z_0} (R_{tot} \cos(T2) - 2X_C \sin(T2)) - (I_0 R_{tot} + 2V_0) .$
T6	Coefficient of ccosh function in current calculation. $T6 = I_0 - \frac{V_D}{Z_0} \cos(T2) .$
T7	Typed in initial time t_0 .
T8	Typed in discharge duration.
T(4,250)	Computed times.
U(4,25)	Typed in break voltages.
V	Output option; plot option.

iss).

Variable	Usage or Meaning
V1	Initialization option, core option, number of half-cycles of break times or break voltages to be input during initialization, number of half-cycle undergoing computation, number of half-cycles to be output.
V2	Print option; scratch initialization input.
V3	Number of characters in output title; flag whether capacitor voltage is to be plotted. Also used to align print columns.
V4	Flag whether charging current is to be plotted. Also used to align print columns.
V5	Flag whether transformer output voltage is to be plotted. Also used to indicate which break time is to be removed from the break time list during initialization.
V6	Total number of items to be plotted.
V7	Scaling option for plots. Offset for successive MINIPLOT time axes when more than one half-cycle is output in a single call. Several uses during half-cycle initialization.
V8	Number of data points in a given half-cycle (used in output routine). Also used in setting y axis scale.
V9	Flag indicating first pass through initialization routine. Also used in choosing source of initial conditions (see statements 14030 to 14068).
V\$,V1\$	Scratch input variables for the output routine.
V5\$,V6\$	Output image masks.
W1	Dash code (PEPSUB), symbol code (MINIPLOT).
W2	Maximum value, horizontal plot axis.
W3	Minimum value, horizontal plot axis.
W4	Maximum value, vertical plot axis.
W5	Minimum value, vertical plot axis.

<u>Variable</u>	<u>Usage or Meaning</u>
W6	Number of points to be plotted.
W7	Number of half-cycles to be output.
W1\$	Plot status.
W2\$	Plot Title.
W3\$	Vertical axis label.
X1,X2 } Y1,Y2 } Z1,Z2 }	Input parameters to interpolation routine FNL.
X(1000)	Plot output buffer, X axis.
Y(1000)	Plot output buffer, Y axis.
Y1\$	Plot abort flag.
X,Y,Z variables	Internal variables for PEPSUB and MINIPLOT.

Appendix E

PROGRAM FOR MINICOMPUTER CONTROL
OF DISCHARGE TIMING

I. Introduction

Software is described for use with an Automated Data Systems (Madison, WI) 1800 A decimal minicomputer for timing (and thus, indirectly, voltage) control of discharge triggering. The hardware and its operation were described in Chapter III. The software, called "Selectabreak" is an assembly language program providing inter- and intra-half-cycle discharge timing and either manual or automatic choice of patterns from among five user supplied patterns plus a "zero break" pattern (no discharges during a half-cycle). Up to 25 breaks per half-cycle and control intervals as long as $37\frac{1}{2}$ days are possible.

Selectabreak was written so as to minimize execution time and memory space required. Linear, easily followable structure was sacrificed to achieve these goals. Thus subroutines are interwoven and a simple flowchart is difficult to draw.

A flowchart which is conceptually complete, but avoids complications produced by interweaving subroutines where possible,

ess).

is shown in Figure E-1. There are two types of operation, manual and automatic. The type of operation invoked at startup is chosen by appropriately entering numbers in memory (see below) and can be changed during execution from the keyboard. In manual operation, one pattern runs continuously. In automatic operation, a preselected sequence of patterns is rastered through. In either case, the total number of half-cycles per control interval may be selected.

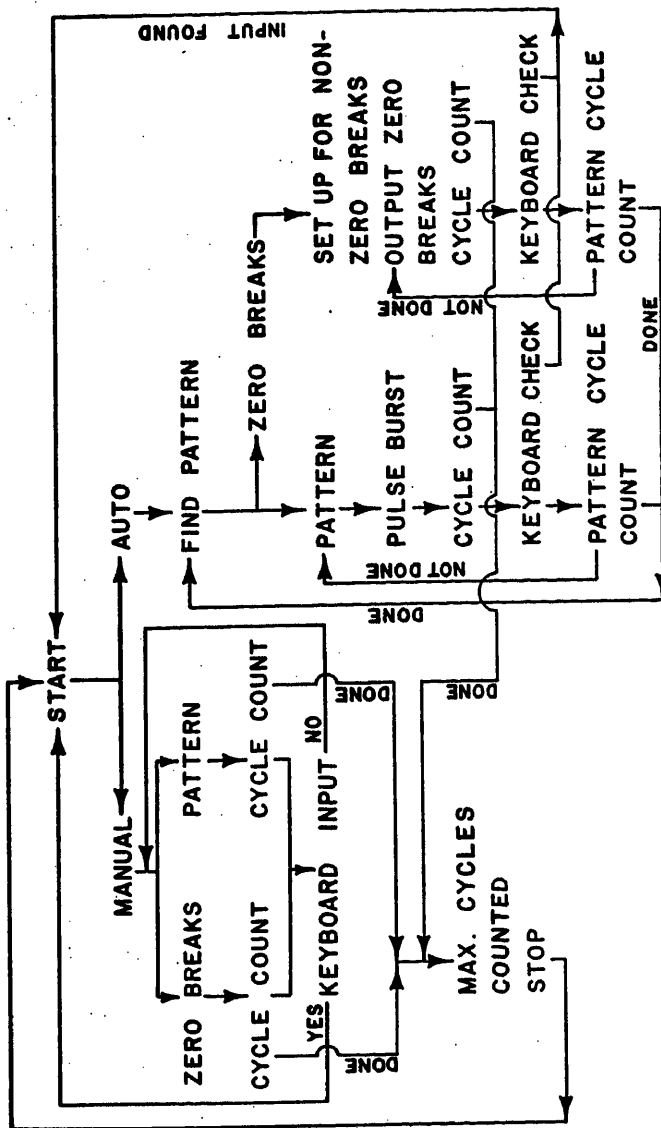
In manual operation, one pattern is selected and is continuously output until (a) the control interval is over and the program stops, or (b) keyboard input indicates a change of mode. Different routines are used for zero break operation than for nonzero break operation.

In automatic operation, the different patterns are automatically sequenced and the time for which a given pattern is used is controlled as well as the total control interval length. Again a separate routine is provided for zero break operation and keyboard input may change the type or sequence of operation.

Program operation can thus be seen to be a number of interwoven activities: (1) outputting a given timing pattern for discharge timing and triggering, (2) pattern selection, (3) half-cycle counting for both individual patterns and control intervals, and (4) input, either prior to or during a run, concerning operation sequence.

Figure E-1

Flowchart of Program Selectabreak



Safety note: To cease pulsing by the digital delay generator at any time, press

Stop
Clear keyboard
24
Load address
Step

If the computer is operating, other simpler procedures may work. The above procedure works from the moment the program is loaded and is immune to RF interference and other possible problems.

II. Loading the Program

The program with a default automatic pattern sequence ready to run, is on a cassette tape. To load the program, follow these steps:

- (1) Computer power on, clear keyboard. Place tape into tape read drive. Zero crossing detector and digital delay generator on if program is to be tested as soon as it is loaded.
- (2) 850, load address
- (3) Enter the following program (the bootstrap tape loader). Punch the five digits starting from the left followed by a "decimal point" which enters the command in memory. Addresses are provided to facilitate checking later.

ress).

<u>Address</u>	<u>Command</u>
850	27003.
851	27006.
852	11862.
853	27008.
854	11856.
855	11851.
856	27090.
857	05903.
858	03857.
859	05857.
860	10000.
861	11851.
862	27004.
863	10600.
864	11850.

(4) Auxilliary information:

- (a) Location 857 is modified when the subroutine is run, so must be set before any reruns. Otherwise the program is self-contained.
- (b) The bootstrap loads the first program on the tape verbatim starting at location 903. This first program should be TREAD/TWRITE, the tape handler.

(5) To check that entry of the bootstrap is correct,

- (a) Set rotary switch to MEM.
- (b) 850, load address.
- (c) Press "examine" button to raster through memory to confirm entries are correct. Should an incorrect entry appear, it may be corrected immediately.
For example, if the entry in location 859 were

05856 (last digit erroneous), instead of pressing
"examine" to go to the next location the entry

05857.

could be made to both deposit the correct entry
and move to location 860.

(6) Load the main tape handler

- (a) Check tape is loaded, label up and to the rear of the drive.
- (b) 850, load address, step.
- (c) Press rewind on tape deck. When tape is done rewinding, press stop on deck.
- (d) 862, load address, start. Be sure to press "start" exactly once here.
- (e) Set tape drive to "play" with volume control (on side of drive) set to 4. Press computer start again.
- (f) Computer display should count rapidly 05903, 05904,... for a few seconds, then stop. Bootstrap is now loaded. Do not change any tape settings; go directly to loading the program.

(7) Loading program "Selectabreak"

- (a) 997, load address. A number 00001 will be displayed. Press 131. to enter the program

identification number. The computer is now at location 998; if the rotary switch is set to MEM, the number 15951 should appear. If it does, go to step (7b). Otherwise, go back to step (5). If a second error occurs, try "playing" with the volume control.

(b) Press start. When the computer stops, press stop on the recorder as well.

(c) Test program.

(1) 24 load address.

(2) Check that delay generator and zero crossing detector are on.

(3) Press start. The sequence 1-2-3-4-5-6-3-2-1-6-1-6 should be displayed twice on the display panel, lasting a total of 8.5 seconds. If this occurs, program is loaded correctly.

Common problems and solutions are:

(a) Computer "hangs" near the start of the sequence. Stop computer, check that DDG and zero crossing are turned on, check with oscilloscope for zero crossing pulses, and check that DDG will work in "period" mode. Go to location 24 and try again.

- (b) Pattern 4 lasts $\approx$ twice as long as other patterns. Program did not load correctly. First, try recycling to step (7a). If that does not work, go back to step (5).

III. User Input and Control

A. Overview of controls

There are a large number of items which a user may control in this software. Many of them are conceptually interactive.

Because default values for all parameters appear in the program, each parameter's effect may be learned independently, though in practice all will likely be varied as a group. Starting at the level of the control interval and working to finer time units, control parameters are:

- (1) Length of control interval (in half-cycles).
- (2) Operation type (manual or automatic).
- (3) Pattern choice (manual mode) or order of patterns (automatic mode).
- (4) Patterned interval duration for each of the automatically rastered patterns.
- (5) Discharge timing within patterns.

Adjustment of these will be described in order. Then procedures for actually running the program will be given.

B. Control interval level commands

The duration of a control interval is determined in units of half-cycles. One hundred twenty half-cycles equal one second.

The duration of a control interval may be considered to fall into one of three categories:

- (1) $< 2\frac{1}{2}$ minutes
- (2) indefinite, but long
- (3) $> 2\frac{1}{2}$ minutes, but definite.

If (3) is the case, the additional software discussed in Section V below is necessary to achieve control. However, the method used to achieve such control is similar to that used in case (1).

To get essentially continuous operation (case (2)), the program is configured to prevent the automatic counter from stopping the program. This is done by doing the following after the program is loaded and before it is started:

```
Clear keyboard
343 load address
Clear keyboard, enter.
```

If at a later point timed operation is desired, the original command must be reinserted:

```
Clear keyboard
343 load address
11070. (enter)
```

ess).

For case (1) control, determine the burn duration desired in seconds. Multiply by 120, and enter this number in memory location 358, the Master Counter. Example: The default pattern lasts $8\frac{1}{2}$ seconds.

$$8.5 \times 120 = 1020 \text{ half-cycles.}$$

Indeed in the program listing (Section IV) in location 358 is the number 1020.

The operation type is chosen by selecting the "initial mode" (location 367). Possible entries are numbers 1 through 8 (actually 00001 through 00008--lead zeros will be omitted henceforth).

Numbers 1 through 6 are manual modes; 7 and 8 are automatic modes.

In automatic mode, control is sequentially given to choosable permutations of the manual modes. Manual modes 1 through 5 are user settable break patterns. Mode 6 is zero breaks per half-cycle. No mode 1-5 should ever be programmed as zero breaks.

In mode 8, the program starts at the beginning of the mode sequence (chosen as described in III.C.2 below), runs through the entire sequence, and goes back through from the start until the Master Counter number of half-cycles have been run. Mode 7 operates in the same fashion except that on startup control begins wherever in the sequence control terminated on a previous run. This might be at the start, but could also be anywhere in the patterned interval depending on where the previous run stopped.

ess).

C. Choice of pattern order and repetition

(1) In manual mode the initial pattern chosen runs continuously until the control interval is over unless the pattern is manually changed. To manually select a pattern number while the program is running, the steps are:

Clear keyboard
[Hit single key 0 through 8]
Press "."

The new pattern will commence running. Entries 1-8 select modes in the same manner as the initial mode setting described above. Mode 0 is a special entry which stops the program and shuts down the DDG so that no further pulsing occurs. In general, the sequence "Clear keyboard, enter" or "Clear keyboard, 0, enter" will stop sparking and leave the computer in a state correct for restarting execution. In some cases RFI may prevent this from working. In that case, use the procedure given in the "safety note" at the end of Section I above.

If an illegal entry is attempted, the number will be placed in an error trap (location 366) and execution stopped.

Note that it is possible to switch not only among manual modes but also from manual to automatic modes. When automatic execution is occurring, one may also use the keyboard to switch to manual modes.

(2) For automatic operation the sequence of patterns is stored as a list in memory. Also stored is the number of times each pattern is to be used before switching to the next pattern in the sequence. The ordered list of patterns occupies locations 400-499, and the list of how long each pattern is to be used occupies locations 500-599. In the default sequence, most of the patterns are used for 30 half-cycles ($\frac{1}{4}$ s) before the next pattern is accessed. This pattern counting feature is used to reduce core space and programming time required compared to simply listing the patterns in order (entering the same pattern number 30 times in a row would have been both tedious and error prone).

Legitimate patterns are any of the manual patterns 1-6. There is no internal check that patterns are correctly chosen.

Following the list of pattern order and also following the list of pattern repetition number, the entry "00000" must be inserted. This is the program flag for indicating list termination.

An example setup would be a pattern that ran as follows:

- 30 half-cycles of pattern 1

- 25 half-cycles of zero breaks (pattern 6)

- 60 half-cycles of pattern 3

- 10 half-cycles of zero breaks

Repeat as long as necessary (limit by the Master Counter).

The order of patterns is: 1, 6, 3, 6. The order of repetitions is: 30, 25, 60, 10. So entries in memory would be:

<u>Location</u>	<u>Entry</u>	<u>Location</u>	<u>Entry</u>
400	00001	500	00030
401	00006	501	00025
402	00003	502	00060
403	00006	503	00010
404	00000	504	00000

There are $30 + 25 + 60 + 10 = 125$ half-cycles per repeating patterned interval. It may be expected that the Master Counter would be set to some multiple of 125 half-cycles.

D. Timing within patterns

At this point instructions have been given on how to output patterned intervals of variable length and sequence. What remains is to define the patterns to be output. This is done by storing information for each of the five user definable patterns giving (a) delay from the zero crossing pulse for the first discharge of a half-cycle and (b) delays for subsequent discharges from the preceding discharge.

For a one-break pattern, only (a) is entered. Data for both (a) and (b) are entered as a single list in memory. The only difference between (a) and (b) is that (a) must be manipulated to account for any asymmetry in the zero crossing detector pulse.

Suppose a five-break pattern is to be inserted in pattern 5 (the default pattern as given in the program listing will be used for the example). From computation perhaps, it is known that breaks are desired at the following times with respect to

the zero crossing of the line (which does not necessarily correspond to the zero crossing pulse):

2000 μ s
 3192 μ s
 4014 μ s
 4741 μ s
 5499 μ s

This must be converted to a series of delay times rather than absolute times. The first delay remains 2000 μ s, defining $\tau=0$ as the time of line zero crossing. The other delays are:

3192 - 2000 = 1192 μ s
 4014 - 3192 = 822 μ s
 4741 - 4014 = 727 μ s
 5499 - 4741 = 758 μ s .

For the zero crossing detector in use, an offset of 160 μ s had been observed. Thus the first delay has to be increased by 160 μ s to 2160 μ s. The list of delays then is

2160
 1192
 822
 727
 758

As in Section C above, the end of a list of data is indicated by entering a 0 in memory. Pattern 5 may thus be loaded:

ress).

<u>Location</u>	<u>Entry</u>
800	02160
801	01192
802	00822
803	00727
804	00758
805	00000

The five user programmable patterns are entered starting at the following memory locations:

<u>Pattern</u>	<u>Starting Location</u>
1	600
2	650
3	700
4	750
5	800 (see above example)

Up to 49 delays per pattern are possible.

E. Limitations and circumventing them

Limitations to software use fall loosely into two categories:

(1) RFI problems and (2) execution speed limitations.

Radio frequency interference from unshielded sparks can cause the computer to jump out of proper sequencing loops and lose control of source operation. Such loss of control is usually audible and is readily confirmed using oscilloscopic monitoring of capacitor voltage. Use of the safety stop procedure in Section I can bring run-away situations under control. Shielding

of leads and breaking of ground loops, especially those involving the zero crossing detector, have proven effective in limiting RF problems. RFI is lower at 10 breaks per half-cycle than at 1 break, all else equal.

The software is sufficiently slow that no breaks may occur within 140 μ s before or after the zero crossing or within 140 μ s of another spark. Further, breaks within 300 μ s of the end of a half-cycle may cause unstable operation if the zero crossing pulses are asymmetric. This latter problem may be overcome to a degree by triggering only off alternate zero crossing pulses. Then delays for two sequential half-cycles are entered as though they were part of a single half-cycle. Recall that a half-cycle at 60 Hz lasts 8333 μ s. Then

$$\text{inter-half-cycle delay} = \begin{cases} \text{time from last spark of first} \\ \text{half-cycle to end of first half-cycle} \\ + \text{time from beginning of second} \\ \text{half-cycle to first spark in that} \\ \text{half-cycle.} \end{cases}$$

For the five-break pattern given above, the end of the first half-cycle occurs

$$8333 - 5499 = 2834 \mu\text{s}$$

after the last spark. The inter-half-cycle delay would be

$$2834 + 2000 = 4834 \mu s .$$

To string the two half-cycles together, the pattern entered would be:

<u>Location</u>	<u>Entry</u>
800	02160
801	01192
802	00822
803	00727
804	00758
805	04834
806	01192
807	00822
808	00727
809	00758
810	00000

Residual problems may arise due to source hardware asymmetry, but these may be "tuned out" by slightly varying delays.

Note that whenever either a zero crossing or a break is detected by computer hardware, both zero crossing and "latch" flags are cleared. Thus the above procedure works on all but zero break patterns. Also, the Master Counter will count whole cycles, not half-cycles, when such a procedure is used.

Experience has shown that, in tuning in a pattern, one delay should be left unchanging, so that some pattern property remains fixed for comparison and nulling.

ress).

F. Running the program

After loading and setting parameters, press:

24 load address
start.

The program will run, stopping at location 81.

To rerun the program, whether internal parameters have been changed or not, start at location 81. This may be done simply by pressing "start" or, if parameters have been changed, by pressing

81 load address
start.

Only in the event of radio frequency interference caused shutdown should it be necessary to go back to location 24 for a start after the first startup for a day.

The mode may be manually changed or the run stopped while the program is executing using the method from Section III.C above.

G. Summary

User settable locations and controls are:

<u>Item</u>	<u>Location</u>
Master Counter	358
Initial Mode	367
Infinite loop	343
Pattern sequence	400-499
Pattern repetition	500-599
Pattern 1	600-649
Pattern 2	650-699
Pattern 3	700-749
Pattern 4	750-799
Pattern 5	800-849
Long count timer (see Section V)	371

IV

Listing of Program Selectabreak

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Address	Tag	Mnemonic	Code	Comment
24	Shutdown	SOB 6	20116	Stop DDG
25	Start	INZ	10800	Initialize
26		SOB 6	20115	Set DDG to "remote",
27		SOB 8	20118	"Delay mode",
28		SOB 2	20112	and 1.0 us resolution
29	Restart	LDA Initmode	04367	Set up initial
30		STA Mode	05352	Operating mode.*
31		CLR Temcount	09357	Clear half-cycle counter.
32		CLR Error	09366	Clear error trap.
33		CLR Flag	09369	Clear keyboard flag.
34	Vector	SIX Six	07359	Choose Mode:
35		JMP Manual 1	11040	Manual
36		JMP Auto1	11125	Auto
40	Manual 1	JMS Cleanup	15060	Clear remains of previous half-cycle.
41		LDA Mode	04352	Set pattern
42		STA Patnum	05353	number.
43		JMS Patload	15100	Set data pointers.
44		LDA Patnum	04353	
45		DAC	10000	Display pattern number.
46		SUE Six	06359	Zero break pattern?
47		JMP Manz	11053	Yes, zero breaks.
48	Cycle	JMS Latch	15325	Output first delay
49		JMS Zerxing	15295	Await zero crossing
50		JMS Pulse	15314	Deliver remaining delays.
51		JMS Recyc	15109	Recycle to start of pattern.
52		JMP Cycle	11048	Repeat pattern.
53	Manz	JMS Zebkr	15280	Output zero breaks
54		JMP Manz	11053	until keyboard command input.
60	Cleanup		00000	Finish up previous pattern if necessary.
61		LDA Flag	04369	Access flag
62		IND	10010	Flag=0 then
63		JMP Cleanup	14060	return
64		CLA Flag	09369	Else clear flag
65		LDA Patnum	04353	get pattern number.
66		SUE Six	06359	Is pattern zero breaks.
67		JMPI Cleanup	16060	Yes--done.
68		JMS Last	15345	No--finish half-cycle.
69		JMPI Cleanup	16060	End of subroutine.
70	Stop	LDA Patnum	04353	Get present pattern.
71		SUE Six	06359	Zero breaks?
72		JMP Stop2	11079	Yes--stop CPU
73		JMS Last	15345	No--await last break.
74		ILA Mode	04352	Get mode
75		SUE Eight	06360	Auto mode?
76		JMP Autostop	11083	Yes--cock system for restart.
77		JMS Recyc	15109	No--reset manual pointers.
78		JMS Latch	15325	Latch out first delay of next pattern.
79	Stop2	SOB 6	20116	Disable DDG

* STA does not clear accumulator. Data used at location 34.

ress).

Address	Tag	Mnemonic	Code	Comment
80		HLT	10600	Halt
81		ROB 6	20126	Enable ODG
82		JMP Restart	11029	Reinitialize and go.
83	Autostop	ILA Mdcnt	03355	Increment half-cycle count
84		STA Mdcnt	05355	for pattern.
85		SUE Mdcntmx	06356	Reached pattern max.
				half-cycles?
86		JMP Stop3	11090	Yes--set to next pattern
87		JMP Stop2-2	11077	No--shut down.
90	Stop3	JMS Pataqu	15150	Get info. for next pattern.
91		LDA Patnum	04353	Get pattern number
92		SUE Six	06359	Zero breaks?
93		JMP Stop2	11079	Yes--shut down
94		JMP Stop2-2	11077	No--set up delay, then
				shut down.
100	Patload	#	00000	Set pointers at start of
				next pattern.
101		LMQ Incre	34364	Compute pattern
102		MPY Patnum	38353	Starting address.
103		SMQ Stdpt	35351	Stdont =
104		LDA Base	04363	Patnum*50 + 550
105		ADD Stdpt	01351	
106		STA Stdpt	05351	
107		JMS Recyc	15109	Set counter to
108		JMPI Patload	16100	first point; return
109	Recyc	#	00000	Set counter to first delay
				location
110		LDA Stdpt	04351	Get address
111		STA Dpnt	05350	Load counter/pointer
112		JMPI Recyc	16109	Return
115	Automdst	#	00000	Reset auto-sequence pointer
116		ILA Six	03359	Set mode
117		STA Mode	05352	to 7
118		CLR Seq	09354	Move to first
119		JMPI Automdst	16115	pattern in sequence.
125	Auto1	JMS Cleanup	15060	Clear history.
126		LDA Mode	04352	Get mode.
127		SUE Eight	06360	7 or 8?
128		JMS Automdst	15115	8--start at beginning
129	Auto2	JMS Pataqu	15150	Get pattern pointers.
130		LDA Patnum	04353	Get pattern number.
131		SUE Six	06359	Zero breaks?
132		JMP Autoz	11142	Yes--go to routine.
133	Cyclea	JMS Latch	15325	No--output first delay
134		JMS Zerxing	15295	Await zero crossing
135		JMS Pulse	15314	Deliver remaining delays
136		JMS Recyc	15109	Set up next half-cycle
137		ILA Mdcnt	03355	Increment half-cycle
138		STA Mdcnt	05355	counter for this pattern
139		SUE Mdcntmx	06356	Move to next pattern?
140		JMP Auto2	11129	Get next pattern.
141		JMP Cyclea	11133	Stay with present pattern.

ress).

Address	Tag	Mnemonic	Code	Comment
142	Autoz	JMS Zebrk	15280	Output zero breaks
143		ILA Mdcnt	03355	count half-cycles of
144		STA Mdcnt	05355	this pattern.
145		SUE Mdcntmx	06356	Done with pattern?
146		JMP Auto2	11129	Yes--get next pattern?
147	Pataqu	JMP Autoz	11142	No--stick with zero breaks.
150		J	00000	Pattern acquisition and set up routine.
151		LDA Seq	04354	Access
152		ADD Forhun	01361	number
153		STA Scratchadr	05365	of
154		IND	10010	next
155		LDA Scratchdr	04365	pattern.
156		JMP Fullcir	14171	If pattern = 0, restart sequence
157		STA Patnum	05353	Set pattern number.
158		DAC	10000	Display pattern number.
159		LDA Seq	04354	Access number
160		ADD Fivhun	01362	of half-cycles
161		STA Scratchadr	05365	This pattern
162		IND	10010	is to be
163		LDA Scratchadr	04365	used.
164		STA Mdcntmx	05356	And store same.
165		CLR Mdcnt	09355	Clear counter.
166		JMS Patload	15100	Set start address of delays.
167		LDA Patnum	04353	Get pattern number.
168		SUE Six	06359	Zero breaks?
169		JMP Zersearch	11173	Yes--find first nonzero breaks.
170		JMP Incseq	11192	No--increment sequence number.
171		CLR Seq	09354	Restart sequence.
172		JMP Pataqu+1	11151	Access pattern.
173		ILA Seq	03354	Find first post zero breaks delay time.
174		STA Zercnt	05368	Look forward;
175		ADD Forhun	01361	find
176		STA Scratchadr	05365	next
177		IND	10010	pattern
178		LDA Scratchadr	04365	number
179		SUE Six	06359	Zero breaks again?
180		JMP Again	11195	Yes--try again
181		JMP Redo	14197	No--end of sequence?
				If yes--start at beginning again.
182		STA Patnum	05353	Latch out first
183		JMS Patload	15100	postzero breaks
184		JMS Latch	15325	delay.
185		IND	10010	Set up dummy
186		LDA Stdpnt	04351	delay for use in
187		STA Zerlatch	05370	clearing flags. See 289-290.
188		LDA Six	04359	Reset pointers to
189		STA Patnum	05353	zero breaks.
190		JMP Incseq	11192	Increment sequence counter.

ress)

Address	Tag	Mnemonic	Code	Comment
192	Incseq	ILA Seq	03354	Increment sequence
193		STA Seq	05354	pointer.
194		JMPI Pataqu	16150	Return.
195	Again	ILA Zercnt	03368	Go to next pattern in
196		JMP Zersearch+1	11174	Search of nonzero breaks.
197	Redo	CLA	10100	Go back to start of sequence
198		JMP Zersearch+1	11174	in search of nonzero breaks
				pattern.
280	Zebrk	Ø	00000	Zero breaks run routine
281		S0B 6	20116	Shut down DDG
282		JMS Zerxing	15295	Await zero crossing
283		CLR Zercnt	09368	Initiate lockout loop.
284		ILA Zercnt	03368	Run loop
285		STA Zercnt	05368	counter
286		SUE Incre	06364	Done with 1 ms delay?
287		JMP ..+2	11289	Loop over--jump out
288		JMP ..-4	11284	Keep looping.
289		LDA Zerlatch	04370	Latch out fake delay
290		SLHRD	27580	to clear flags.
291		ROB 6	20176	Turn DDG on again.
292		JMS Cyccount	15339	Count total half-cycles
293		JMS Kybd	15300	Check for user input
294		JMPI Zebrk	16280	Return
295	Zerxing	Ø	00000	Await zero crossing
296		SLSNF2	27500	look for flag
297		JMPI Zerxing	16295	flag found--return
298		JMP ..-2	11296	no flag--look again
300	Kybd	Ø	00000	Run time input routine
301		RKB	10700	Look for input
302		JMP ..+2	11304	Input found--use it
303		JMPI Kybd	16300	No input--return
304		JMPØ Stop	14070	Input=0; stop.
305		STA Mode	05352	Set mode based on input.
306		ILA Error	03366	Set flag indicating
307		STA Flag	05369	input occurred.
308		LDA Mode	04352	Is mode
309		SIG Eight	07360	legal?
310		JMP Vector	11034	Yes--use it
311		STA Error	05366	no--store mode in error trap.
312		JMP Stop	11070	and stop.
314	Pulse	Ø	00000	Latch out pattern.
315		JMS Latch	15325	Latch out delay
316		JMP Cont	11318	continue with pattern.
317		JMPI Pulse	16314	End of half-cycle; return.
318	Cont	SLRTON	27503	Retrigger on.
319		SLSNF 1	27505	Await spark firing.
320		JMP Pulse+1	11315	Spark fired--latch out next
				delay.
321		JMP ..-2	11319	No spark yet; wait.

Address	Tag	Mnemonic	Code	Comment
325	Latch		00000	Output delays.
326		IND	10010	Get
327		LDA Dpnt	04350	delay time
328		JMPD Eohs	14333	if=0, end of half-cycle
329		SLRD	27580	latch out delay
330		ILA Dpnt	03350	Increment pointer to
331		STA Dpnt	05350	next delay.
332		JMPI Latch	16325	Return.
333	Eohs	JMS Cyccount	15339	Count total half-cycles.
334		JMS Kybd	15300	Look for user input.
335		JMS Last	15345	Await last break.
336		ILA Latch	03325	Increment return address.
337		STA Latch	05325	Return to location 1
338		JMPI Latch	16325	instruction after normal return address.
339	Cyccount		00000	Count half-cycles.
340		ILA Temcount	03357	Count half-cycles.
341		STA Temcount	05357	Save count.
342		SUE Mastrcnt	06358	Total cycles done?
343		JMP Stop	11070	Yes--stop
344		JMPI Cyccount	16339	No--continue
345	Last		00000	Await last break of half-cycle.
346		SLRTOF	27504	Retrigger disable
347		SLSNFI	27505	Break yet?
348		JMPI Last	16345	Yes--return.
349		JMP --2	11347	No--wait.
350	Variables	Dpnt	00600	Address of next delay
351		Stdptnt	00600	Starting address of present pattern delays.
352		Mode	00007	Operating mode 1-8
353		Patnum	00001	Pattern number in use.
354		Seq	00000	Position in auto sequence
355		Mdcnt	00000	Half-cycles fired in present pattern.
356		Mdcntmx	00100	Total half-cycles to be fired of the present pattern.
357		Temcount	00000	Half-cycles so far in control interval
358		Mastrcnt	01020	Total half-cycles in control interval
359		Six	00006	digit 6
360		Eight	00008	digit 8
361		Forhun	00400	Used to access
362		Fivhun	00500	auto-sequence
363		Base	00550	information and
364		Incre	00050	pattern delays
(Incre is also used to generate the zero breaks delay.)				
365		Scratchadr	00400	Address scratch pad.
366		Error	00000	Error trap 0=no error
367		Initmode	00008	Mode at start up.

Address	Tag	Mnemonic	Code	Comment
368		Zercnt	00000	Counter for zero breaks.
369		Flag	00000	Data input flag.
370		Zerlatch	01000	Dummy delay for zero breaks latch-out.
400	Pattern Order	Sample	00001	
401			00002	
402			00003	
403			00004	
404			00005	
405			00004	
406			00003	
407			00002	
408			00001	
409			00006	
410			00001	
411			00006	
412			00000	
500	Half-cycles	Sample	00030	120 half-cycles=1 second
501	Per Pattern		00030	
502			00030	
503			00030	
504			00030	
505			00030	
506			00030	
507			00030	
508			00030	
509			00060	
510			00120	
511			00060	
512			00000	
600	Break Patterns	One	04500	
601			00000	
650		Two	02000	
651			04000	
652			00000	
700		Three	01500	
701			03000	
702			03000	
703			00000	
750		Four	01000	
751			02000	
752			02000	
753			02000	
754			00000	
800		Five	02160	
801			01192	
802			00822	
803			00727	
804			00758	
805			00000	

Address	Tag	Mnemonic	Code	Comment
Additional code for prolonged control intervals (> 2½ minutes)				
200	Longcyc	Ø	00000	Start of long count routine.
201		CLR Temcount	09357	Clear short counter.
202		ILA Bigcnt	03372	Count long cycle.
203		SUE Bigmax	06371	Done?
204		JMP Longreset	11207	Yes--reset and stop
205		STA Bigcnt	05372	No--save count
206		JMPI Longcyc	16200	and continue
207	Longreset	CLR Bigcnt	09372	Clear counter for next run.
208		JMP Stop	11070	Stop
343		JMS Longcyc	15200	Call long count routine.
371	Bigmax	6	00006	Number of long cycles to be run
372	Bigcnt	0	00000	Long cycle counter.

V. Control Intervals Longer than $2\frac{1}{2}$ Minutes

The last section of the program listing gave modifications to the standard Selectabreak package which allow control intervals longer than $2\frac{1}{2}$ minutes. In fact, control intervals of over one month are feasible. The routine works as follows: When the Master Counter indicates that the usual Selectabreak control interval is over, instead of stopping, a "long cycle counter" is incremented. The normal program is instantaneously rerun (in any desired mode) until a fixed number of long cycles have occurred, at which time the program stops. Thus user control of prolonged control intervals consists of loading the modified program from tape (program 132) and entering a maximum for the long cycle counter in a manner analogous to the Master Counter. This additional input goes into location 371. The total number of half-cycles for the long control interval is the number in location 371 times the number in location 358. In the defaults on the tape, location 371 = 6, location 358 = 1020 as above. So the net burn is 6×1020 half-cycles or $6 \times 8\frac{1}{2}$ seconds or 51 s.

The only statement changed from the original program is statement 343 which is changed from 11070 to 15200. Other statements are additions.

Note that the long cycle counter is reset at the end of a run, not at the beginning. Thus if the program is stopped manually from the keyboard or by RFI, the long cycle counter

(location 372) must be reset to "0" before another run is made. If a run is stopped under counter control, then no manual resetting is necessary.

Note that the instructions for program loading are the same as those given in Section II except that the number 132 is substituted for 131 throughout step (7).

VI. Variable List

<u>Name</u>	<u>Location</u>	<u>Meaning or Use</u>
Again	195	Start again at beginning of auto-sequence pattern listing looking for a nonzero break pattern.
Auto1	125	Beginning of auto-sequence routine.
Auto2	129	Get next pattern in sequence and branch for zero or nonzero breaks.
Automdst	115	Reset pointers to start of auto-sequence.
Autostop	83	During shutdown leave system ready to run in mode 7 on startup if desired.
Autoz	142	Output zero breaks during auto-sequencing.
Base	363	=550. Used in computing addresses of pattern delay data.
Bigcnt	372	Long cycle counter.
Bigmax	371	Value of Bigcnt when program is to halt--set by user.
Cleanup	60	Finish off previous half-cycle following keyboard input.
Cont	318	Awaits spark firing in mid-pattern (all but last break).

Name	Location	Meaning or Use
Cyccount	339	Runs the Master Counter.
Cycle	48	Output manual nonzero break pattern.
Cyclea	133	Output auto mode nonzero break pattern.
Dpnt	350	Address of next delay.
Eight	360	Digit 8.
Eohs	333	Portion of latching routine invoked after last delay is latched out.
Error	366	Records illegal keyboard entries during a run.
Fivhun	362	Address of start of pattern repetition information.
Flag	369	Indicates when keyboard input occurred.
Forhun	361	Address of start of pattern order information.
Fullcir	171	Gone through auto-sequence--reset to start of sequence.
Incre	364	Number of memory locations per set of delay times. Also used to generate a waiting period in zero break pattern.
Incseq	192	Increment sequence position in auto-sequence mode.
Initmode	367	Mode when program is started.
Kybd	300	Access runtime keyboard input data.
Last	345	Await last break of pattern.
Latch	325	Latch out delays to digital delay generator.
Longcyc	200	Routine to allow $> 2\frac{1}{2}$ -minute control intervals.
Longreset	207	Clear long cycle counter and stop.

Name	Location	Meaning or Use
Manual 1	40	Begin manual mode operation.
Manz	53	Manual operation zero breaks routine.
Mastrcnt	358	Total half-cycles for normal (as opposed to long) control interval.
Mdcnt	355	Number of half-cycles output in present pattern.
Mdcntmx	356	Value of Mdcnt when new pattern is to be accessed.
Mode	352	Present operating mode 1-8.
Pataqu	150	Set up next pattern in auto-sequence.
Patload	100	Set pointers at start of new pattern.
Patnum	353	Present pattern 1-6. In manual mode, Patnum=Mode.
Pulse	314	Burp out a half-cycle of break pattern.
Recyc	109	Manual mode pointer reset to first delay of pattern.
Redo	197	Go to start of list in search of nonzero break pattern.
Restart	29	Startup except on initial turn on; best accessed from locations 24 or 81.
Scratchadr	365	Address scratchpad for accessing delays.
Seq	354	Position in auto-sequence list.
Shutdown	24	Initial command and general off switch.
Six	359	Digit 6.
Start	25	Initialize system.
Stdpnt	351	Starting address of delays for present pattern.

Name	Location	Meaning or Use
Stop	70	Shutdown routine.
Stop2	79	Terminal shutdown steps.
Stop3	90	Set up buffers for correct states upon restart.
Temcount	357	The Master Counter.
Vector	34	Choose manual or auto mode.
Zebrk	280	Output one half-cycle of zero breaks.
Zercnt	368	Counter used in zero breaks delay loop.
Zerlatch	370	Contains first post-zero breaks delay during an auto mode zero breaks interval.
Zersearch	173	Find first nonzero breaks pattern and first delay thereof.
Zerxing	295	Look for zero crossing occurrence.

Appendix F

INSTRUMENT OPERATION

This appendix contains an outline for using the 5 m spectrograph/time resolved spectrometer employed in studying the spark discharge. It presupposes knowledge of operation of the 1800 A computer as given in Appendix E. Other helpful information appears in D. M. Coleman's thesis.

I. Use of 1 m Survey System

A. Electronics setup

- (1) Position stand on rail.
- (2) Position source so electrode power leads can comfortably be attached to stand.
- (3) Ground source and rider carrying stand.
- (4) Check (3) with VOM.
- (5) Ground oscilloscope and computer cart.
- (6) Plug zero crossing plug into front of source.
- (7) Plug TM-27 into source; connect TM-27 output to thyatron grid input.

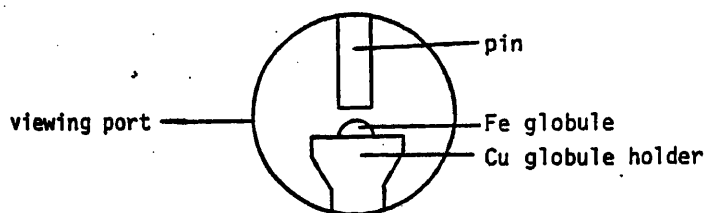
- (8) Plug in 'scope and computer cart--use two prong plugs.
- (9) Bring up 1800 A with desired pattern.
- (10) Oscilloscope on.
- *(11) Connect high voltage probe to oscilloscope, then to source.
- (12) Short source gap.
- (13) Warm up source.
- (14) Select diode polarity and inductance of source (also capacitance if applicable).
- *(15) Connect discharge waveform monitor to 'scope (do not disconnect high V probe at 'scope unless it is disconnected at the source too).
- (16) Connect computer cart control output pulses to TM-27; TM-27 on.
- *(17) Watch V or i waveform on 'scope as you
 - (a) safety off
 - (b) deadman on
 - (c) computer on (as desired)
 - (d) deadman off
 - (e) computer off
 - (f) safety on
- (18) Keep gap shorted and adjust pattern.

B. Gap setup

- (1) Mount electrodes.
- (2) Set gap about ERL and with proper spacing using VOM, height gauge, etc.
- (3) Connect argon; set initial flow.
 - (a) if tank regulator is at 20 psi then
 - (b) set rotameter at 11.3 to get 8 ml/s of Ar.
- (4) Rotate electrode.
- (5) Connect leads from source to gap; select initial cathode at this time (GND electrode = initial anode electrode connected to L_2 = initial cathode).
- *(6) Repeat step A.17--adjust Ar flow for stability.

C. Wavelength reference setup

- (1) Mount globular arc electrodes in arc-stand jaws
 - (a) globule in lower jaw, roughly level with centerline of viewing ports
 - (b) Graphite or iron pin for upper electrode--allow for carriage travel so electrodes can be touched to ignite arc. Geometry:



(2) Connect cooling water

(a) distilled water is pumped through stand.

(b) heat exchanger water, filtered on the lab's north wall, should be at 20 psi.

(3) Decide if glass UV filter is to be used (order sorter).
Position appropriately.

(4) Connect power leads from arc source to stand--red
lead = anode = to globule.

(5) Test the arc (instructions on power supply, "cattle
prod" for shorting electrodes available if racking of
jaws not desired).

(6) Connect Cu hollow cathode lamp to power supply. Surge
V to start, then adjust to 10 mA. Allow ~ one-half
hour warm up before use.

(7) HCDT ("hollow cathode discharge tube") is used directly
behind the spark stand. To do this

(a) rack top electrode up 0.15 inch

(b) place rider for HCDT behind stand, and against rail
stop; this necessitates disconnecting gap to source
leads

(c) place HCDT in kinematic mount on rider.

D. Optics setup

(1) Open covers of two 1 m focal length parabolic mirrors.

(2) Remove lucite cover of plane transfer mirror.

s).

- (3) Remove lucite covers of two small arc transfer mirrors; remove demountable mirror from optical path.
- (4) Set entrance slit to desired width (table attached-- first two columns are for original equipment slits, last column is for in-house mounted slit without exit slit. Find width desired in left-hand column; correct setting for micrometer is in body of table.).
- (5) Set fishtail for 5 mm slit height.
- (6) Set grating to desired wavelength. If using filmback, set λ to 150 Å shorter wavelength than shortest λ line to be observed. Longer λ are at right of film.
(Example: To observe CuI3247.74 Å line at left of film set counter at 3097 Å or less; 3050 Å would work well.)
- (7) Tilt camera transfer mirror so focal plane receives light (lever on front of spectrograph pointing to "in".) Be sure opening where exit slit could go either has a slit in place or is capped (this controls stray light).
- (8) Load film; insert holder in camera back and rack holder to first shooting position (3.5 cm).

*E. Run sequence

- (1) Set fishtail as per D.5 above.
- (2) Room lights off-reds are okay.

TABLE F.1. One m Slit Calibration.

"0" →			
slit →	entrance slit	exit slit	entrance slit
setting →	(to nearest 0.5)		
true width ± (μm)			
5	19.5	6	7
6	21	7	8.5
7	22	8	9.3
8	23.5	9	9.8
9	24	10.5	11.5
10	25	11	13
12	27.5	13.5	15.5
14	29	16	17
16	31	18	19
18	33	19.5	21
20	35	21.5	23
30	45.5	31	33
40	55	41	42.5
50	66	51	52
60	76.5	61	62
70	86	71	72
80	96.5	81	81
90	106	91	92
100	116	101	102
125	143	125	128
150	167	152	152
200	220	*	*
250	*	*	*
300	†	†	*
400	†	†	*
	Data of 3/7/78		Data of 4/25/78

ess).

Footnotes to Table F.1

* Imprecise measurements; extrapolate from narrower slits if desired.

† Do not attempt these settings--micrometer will "bottom" causing movement of head or shaft, necessitating recalibration.

- (3) Spark source and gap connected, argon on, electrode rotating.
- (4) Darkslide up! Hands off the racking mechanism until step (15).
- (5) Source safety off, high voltage on.
- (6) Shutter open.
- (7) Computer on--generates timed burst to expose film.
Exposure guide: At two breaks per half-cycle a 2 s exposure works well from 2300-6500 Å.
- (8) Shutter closed, high V off, safety on.
- (9) Push fishtail in all the way--the bottom hole of the Hartmann diaphragm will be aligned with the slit. Call this hole "# 4" for future reference.
- (10) Disconnect gap from source; rack upper electrode up 0.15 in. Mount hollow cathode.
- (11) Open shutter to lay down HCDT reference spectrum.
20 s - 1 m gives reasonable exposures. (Use shorter of these exposures at > 5500 Å; I shot all my spectra at 20 s, but some reference lines in the violet and UV are too weak.)
- (12) Mount arc transfer mirror that was removed in step D.3 above. Set Hartmann diaphragm to hole #1 by pulling diaphragm out until the detent engages for hole 4. (It may be wise to try this a few times before a run is

attempted when the shutter is not mounted. Thus feel and visual alignment can be compared.)

- (13) If $\lambda < 4100 \text{ \AA}$, run arc without a filter; if $\lambda > 4100 \text{ \AA}$, use glass filter to prevent order overlap.
- (14) Shoot arc spectrum
 - (a) light arc
 - (b) shutter open 2 s ($\lambda < 4100 \text{ \AA}$); 5 s ($\lambda \geq 4100 \text{ \AA}$)
 - (c) shutter closed
 - (d) leave arc on
- (15) Rack plate. Set new λ for exposure.
- (16) Repeat step (14), except arc is already on, and should be turned off when done.
- (17) Remove arc transfer mirror placed in optical path in (12) above.
- (18) Repeat steps (9)-(11) inclusive.
- (19) Remove HCOT and rider from rail. Reconnect spark gap to source and set electrode spacing.
- (20) Repeat steps (1), then (5)-(8).
- (21) Dark slide down whenever pausing or winding film. To preserve λ identity among reference and unknown (spark) spectra, do not pause or lower dark slide between steps (5) and (15) or between (16) and (20) inclusive.

F. Shutdown procedure

- (1) Argon off, electrode unplugged.

- (2) Safety on.
- (3) Mirrors and slits covered.
- (4) Computer off or at least stopped (i.e. TM-27 not being fed trigger pulses).
- (5) Clean up arc stand.
- (6) Cooling H₂O off (at pump and wall).

*Do not operate source unless probe is connected to scope or some alternative ground. Otherwise dangerous voltage appears at the probe output.

II. Use of 5 m Spectrograph Photographically

A. Complete Sections A, B, and C.1-C.3 of Section I.

B. Set up of 5 m optics

- (1) Choose wavelength to be observed.
- (2) Mount entrance slit on 1 m predisperser--use entrance slit without exit slit, i.e. the slit mount with a black tube where the exit slit could be.
- (3) Set slit width and fishtail. Diffraction limited slit widths:

λ	Slit Width
2000 Å	10 μm
4000 Å	20 μm
6000 Å	30 μm

This applies only when 5 m spectrometer is used--widths to 10 or even 5 μm are useable on 1 m spectrometer alone.

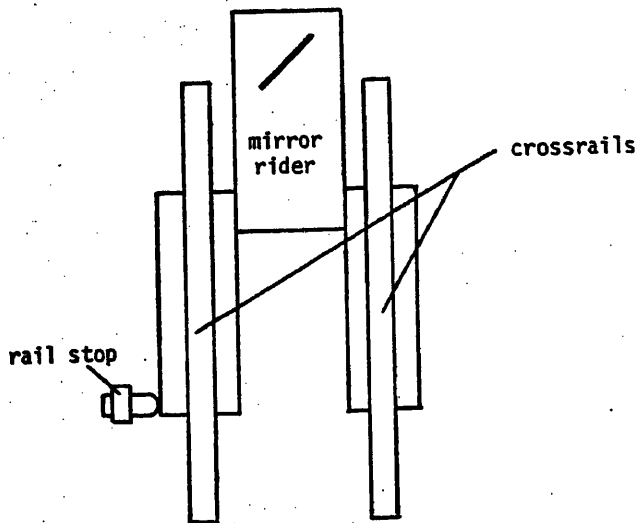
- (4) Set 1 m grating to desired wavelength. Account must be made for slight system misalignment. Thus: To get throughput of wavelength λ , set λ counter of predisperser at

$$\lambda + 4 \text{ \AA}.$$

Example: To get the CuI 3247.54 $\text{\AA}$ resonance line through the system, set the predisperser at

$$3247.5 + 4 = \underline{3251.5 \text{ \AA}}.$$

- (5) Open covers of 8 in. camera and collimator mirrors. Covers should not vignette any light beams, but should also be opened only as far as necessary so that the cover can act as a light baffle.
- (6) Slide the focal plane cross rail/plane transfer mirror assembly so that the south cross rail support rider touches the rail stop at the south end of the east out-rider rail. The transfer mirror rider should touch the opposite corner of the south cross rail support rider, and the other cross rail should in turn touch the mirror support rider. The whole assembly forms a sandwich with the mirror rider in the center and cross rails on the sides:



- (7) Uncover the plane transfer mirror. Mount the film back on the cross rails. Push it forward until the dial indicator shows the film back to be in focus ± 0.001 in. from the value on the black Dymo labeling tape on the rider. (The white label with black pen lettering is from D. M. Coleman's original focussing and is left on the rider for future reference.)
- (8) Remove the lucite grating cover. Touch only the sides of the cover! Work slowly and carefully to avoid at all costs damaging the grating.
- (9) Set the grating angle (counter is on grating mount). Five-digit counter has decimal point after first two digits thus:

dd.fff

angle in fractional
whole degrees degrees

Grating equation:

$$n \lambda = 3.33073 \cdot 10^4 \sin \theta$$

(Example: for $n = 3$

$$\lambda = 3587 \text{ \AA}$$

(A1 II)

$$3 \cdot 3587 = 33307.3 \sin \theta$$

$$\sin \theta = \frac{3 \cdot 3587}{33307.3} = 0.32308233$$

$$\theta = 18.849^\circ$$

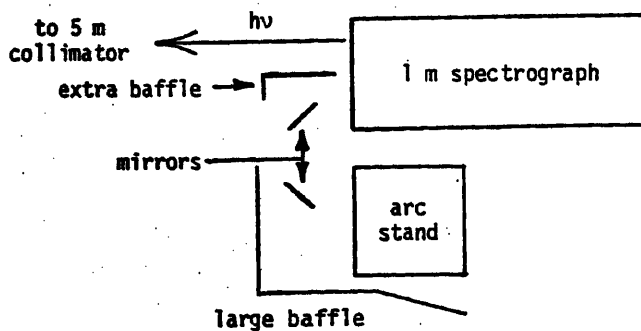
Note both the numerical grating constant and wavelength are in angstroms. Start at least 0.3° below the desired angle and adjust higher to the angle desired. This prevents problems with backlash in the gears.

(10) Load camera back with plate or film.

C. Initial run setup

- (1) Prepare electrodes and stand (Argon on, electrodes aligned, rotating as appropriate.)
- (2) Erect light baffles:
 - (a) cloth completely around spark stand
 - (b) large metal baffle around arc
 - (c) north cover of spark 1 m first collection mirror parallel to cross rails (to block slit reflections)

- (d) when and only when arc is in use, cover from 5 m focal plane transfer mirror may be placed behind the last arc transfer mirror to block extraneous arc radiation:



- (3) All lights off. Doors light sealed. All electronics lights covered insofar as is possible, commensurate with safety and conduction of the experiment.

D. Run

1.
 - (1) Shutter and darkslide on focal plane open.
 - (2) Fire spark for desired exposure.
 - (3) Shutter closed.
2.
 - (1) Arc on.
 - (2) Shutter open.
 - (3) To keep arc lit, feed electrodes together ≈ 1 mm every minute or two.
 - (4) Shutter closed.

3. Exposure guide. For a line showing good intensity near 3100 Å in 2 s in first-order on the 1 m system, the 5 m exposures are roughly as follows:

<u>Order</u>	<u>Grating θ</u>	<u>Time</u>	<u>Observed Intensity</u>
1	5.340	5 m	Faint but clear
4	21.857	2 m	Good exposure
		5 m	Overexposed
7	40.655	8 m	Barely visible

Grating blaze is 1 μ m first-order (17.472°). Rule of thumb: Near blaze, exposure time in seconds on the 1 m is exposure time in minutes on the 5 m. This is a first approximation only!

E. Clean up

- (1) All 1 m clean up is the same.
- (2) Cover 5 m grating and mirrors. Turn the stepper motor power supply off.

F. Note on stepper motor.

To slew the grating, start at a low speed and increase the stepping rate while the motor is running. Otherwise torque is too low and motor freezes in position.

III. Use of 5 m Spectrometer with Time Resolution

The procedure outline will be typical of that used to generate unipolar and bipolar time resolved data May 1-June 15, 197ⁿ

should be regarded as a procedure which works, but not as a definitive approach.

A. Electronics setup

- (1) Position source and stand.
- (2) Ground source; check with VOM.
- (3) Plug TM-27 into source and connect Thyatron trigger lead to rear of TM-27.
- (4) Connect computer cart to ground and plug into wall using two prong adapters.
- (5) Plug zero crossing into barrier strip using appropriate adapter. This is needed for RFI reduction. If the source in use runs off the 250 V main, there will be a 30° shift of the zero crossing pulse with respect to the source charging line.
- (6) In addition to the standard 1800 A/Digital Delay Generator setup, obtain a pulse generator and a second BNC delay generator. A delay line may also be inserted if desired as described below; its use may prove unnecessary.
- (7) To the output of the BNC which is interfaced to the 1800, attach two BNC "T" connectors. This gives three outputs. Connect one of these to the shielded "Delay" line to the 1800 A. The other two connections will be mentioned shortly.

- (8) Connect the zero crossing detector to the computer.
Turn on the computer and load the program.
- (9) If delay line is to be used, connect it to the BNC output and the trigger input of the TM-27. 500 nS delay is appropriate.
- (10) Turn on digital oscilloscope. Set to ± 10 V full scale. Attach P6015 high V probe. Using a DC power supply, set "R5" to get DC signal level of scope/probe combination accurate to 1% or better. Then, using the square wave output of a Tektronix (or other) oscilloscope calibrator, tweak C_2 , R_2 , C_1 , and R_1 to get the top of the square wave as observed flat to $\frac{1}{2}\%$ or better. Connect probe to source when done with calibration.
- (11) With gap shorted, use computer and digital 'scope to set a break pattern.
- (12) Connect the second BNC delay generator:
- (a) Trigger in connected to the third branch of the delayed output on BNC #1.
 - (b) On rear of generator, switch to external clock and connect "clock in" on this BNC to "clock out" on BNC #1.
- (13) Warm up at Tektronix 'scope with 1 A1 or W plugin. Turn on and warm up a Datapulse pulse generator. Besure 'scope is grounded.

ty.

ra-

p.

h.

c-

press).

- (14) Connect the positive Datapulse output to the oscilloscope through a $50\ \Omega$ terminator. Adjust amplitude of pulse (use internal trigger) to 10 V. Pulse width: 100 ns or less.
- (15) Set Datapulse to external trigger. Connect positive output (unterminated) to trigger input of framing camera. Turn framing camera on low voltage only. Also, check at this time that camera mechanical shutter is closed.
- (16) Connect framing camera monitor to I A1 plugin through a $50\ \Omega$ terminator. To the other input, connect the discharge current transformer monitor lead.
- (17) Connect "initial output" of BNC #2 to the B trigger input of the Tektronix 'scope. Set trigger level. For this purpose, switch BNC #2 to "period" mode. When all set, switch to "Delay" mode. Also, set to fastest clock rate (switch at leftmost setting). Connect "delayed output" of BNC #2 to Datapulse trigger in.
- (18) Turn on computer (source off). Set trigger level on Datapulse so that monitor signal appears from TRW camera. Convenient setting for BNC #2: 3.0 μ s delay. Convenient 'scope sweep rate: 1 μ s/div.

- (19) Monitoring TRW pulse and current waveform simultaneously, determine setting of BNC #2 so that TRW pulse occurs at the instant the Thyratron is triggered (call this " t_0 "--probably will be 1 μ s or less).
- (20) Strap cables together for neatness. Sheath any cable > 2 feet long in grounded braid wire. Shield leads from Datapulse to TRW camera.

B. Optics setup

- (1) Demount slits from JACO 1 m spectrometer.
- (2) Slide cross rails and plane transfer mirror $7\frac{3}{8}$ in. north of the position specified in Section II above (a rail stop is provided on the main auxilliary rail). Position the last folding mirror on the cross rails using the dial indicator and distance setting given on the rider.
- (3) Slide the TRW camera south until its support rider touches the rail stop on the eastmost rail just north of the cross rails. System is now aligned and focussed.
- (4) Uncover all mirrors and the grating. Set grating angles in 1 m and 5 m instruments as per II above.

C. Run procedure

- (1) Load camera back--leave darkslide down. Under the dovetail slide, stack "checkers" to give a height of

7 cm. "Checkers" come in sizes 1 cm, 2 cm, 4 cm, and 8 cm.

- (2) Set spark gap, wavelength, and delay time on BNC #2. Recall the zero offset, t_0 , was previously determined. Thus setting time for the BNC is

desired time + t_0 .

Be sure argon is on and electrode is rotating.

- (3) Shroud the stand in black cloth.
- (4) With only red lights on, turn on TRW high voltage. Before turning on white lights, double check that shutter is closed and high voltage is off. Otherwise damage may result.
- (5) All lights out. Source high voltage on. Darkslide up. TRW mechanical shutter open.
- (6) Set the computer to give the desired burn duration.
- (7) Computer on--run the exposure.
- (8) Computer off, darkslide down. Restack the "checkers" (winding film as appropriate) for next exposure. Allowable stack heights are 2-7 cm inclusive. By shooting 7 cm shot first, physical and chronological order of shots is the same. To prevent accidental stray light exposure of film, the darkslide should be lowered whenever the "checkers" are restacked or the film is wound.

- (9) Reset delay or grating angle--recycle to 7.
- (10) Turn off source high voltage whenever an operation takes you within arm's length of the gap. Monitor voltage on the digital 'scope. Wait until voltage registered on the capacitors is < 200 V before approaching gap.
- (11) After last exposure, close TRW mechanical shutter.

D. Shutdown procedure

- (1) Source and TRW high voltage off. Shutter closed.
- (2) Argon off; electrode rotator unplugged.
- (3) Grating and mirrors covered.
- (4) Remount 1 m slits.

IV. Auxilliary Tables: Calibration of Modified Jarrell-Ash Source

This is a compilation of data taken by J. P. Walters and A. Scheeline on a modified commercial spark source. The other major source used, a research source documented by D. M. Coleman, has been similarly characterized; tables appear in Coleman's thesis.

TABLE F.2

$R_{\text{forward bias}}$ 41 K Ω
 $R_{\text{reverse bias}}$ 34 M Ω
 C 0.0101 μF

L as a function of Variac setting:

Setting	Inductance (Henries)
0	16.70
5	17.14
10	18.24
15	19.76
20	21.6
25	22.8
30	23.7
35	24.7
40	25.2
45	25.3
50	25.0
55	24.2
60	23.0
65	21.4
70	19.7
75	18.2
80	17.2
85	16.76

transformer turns ratio: 136.7 ± 0.3

TABLE F.3. Discharge Inductors.

L₁ Adjustment is made using metal rods with spring clamps at each end. In the table below, one end of the rod is connected to the tap labeled "2" on the inductor, and the other end is connected to the tap number shown. Corresponds inductance is shown in the second column.

Tap	Inductance (μH)	Tap	Inductance (μH)
50	2.3 ± 0.2	26	159.0 ± 0.2
48	8.0 ± 0.2	24	174.7 ± 0.2
46	17.1 ± 0.2	22	190.5 ± 1.0
44	27.9 ± 0.2	20	206.0 ± 1.0
42	40.0 ± 0.2	18	222.0 ± 1.0
40	53.6 ± 0.2	16	238.0 ± 1.0
38	67.7 ± 0.2	14	254.0 ± 1.0
36	82.2 ± 0.2	12	270.0 ± 1.0
34	97.1 ± 0.2	10	Inaccessible
32	112.4 ± 0.2	8	301.0 ± 1.0
30	127.8 ± 0.2	Open	367.0 ± 1.0
28	143.4 ± 0.2		

TABLE F.4.

L_2 One end of rod clamped to turn 5 (counting from the bottom of the inductor). Top of rod connected to the turn listed in the first column, with calibration as listed in the second column.

Tap	Inductance (μH)	Tap	Inductance (μH)
97	4.0	57	72.4
93	7.8	53	80.4
89	13.0	49	88.5
85	19.2	45	96.6
81	25.9	41	104.7
77	33.1	37	112.9
73	40.8	33	121.0
69	48.6	29	Inaccessible
65	56.4	25	137.4
61	64.3	21	145.5
		Open	189.7

All are $\pm 0.2 \mu H$.

TABLE F.5.

L_3 Jumper is connected to tap as listed, i.e. tap 1 is closest to outside end of L_3 , tap 16 is closest to ground connection.

Tap	Inductance
16	0.35
15	1.5
14	3.3
13	5.8
12	9.0
11	12.5
10	15.7 ± 0.5
9	20.4
8	22.8
7	25.1
6	28.2
5	31.9
4	36.1
3	40.9
2	46.6
1	51.8
Open	54.6

All $\pm 0.2 \mu\text{H}$ except as noted.

TABLE F.6. Rotameter Calibration for Flow Meter Used for All
Non-Schlieren Experiments.

Reading (bottom of silverball)	Flowrate (ml/s)
0.5	0.18
1.0	0.34
1.65	0.71
2.75 $\pm$ 0.05	1.03
3.58 $\pm$ 0.08	1.55
4.30 $\pm$ 0.1	2.06
5.5	2.82
6.4	3.55
7.5	4.55 $\pm$ 0.1
8.60 $\pm$ 0.05	5.56 $\pm$ 0.2
10.0	6.85 $\pm$ 0.25
11.0	7.81 $\pm$ 0.4
12.0	8.77 $\pm$ 0.45
13.60 $\pm$ 0.1	10.20 $\pm$ 0.5

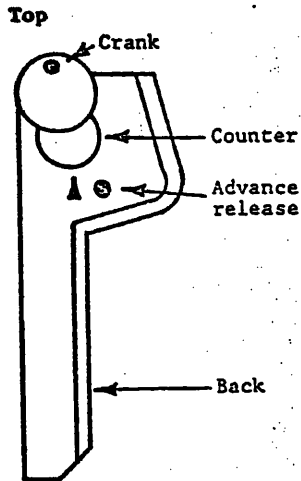
Calibrated at 21.9°C. Typical error limits are shown where known.
For settings ≤ 4.3 , precision was limited by flowrate
fluctuations. Above this setting, limitation is due to ~ 0.5 s
uncertainty in operating the stopwatch used to time flow.

V. Roll Film Holder

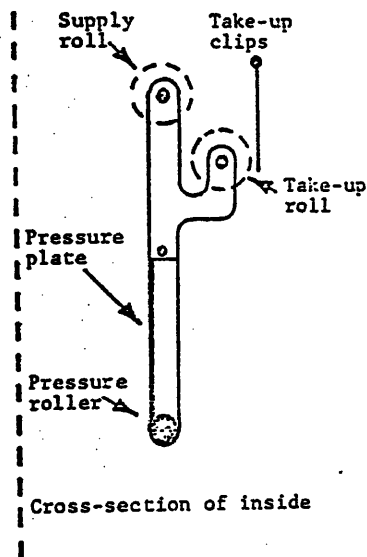
Appended is a copy of the instructions for use of the roll film holder used for spectral work. In the section "Finding and Interpreting Roll Film Spectra" III.B, the orientation shown is specific to the 1 m spectrometer. For both time integrated high wavelength resolution and time resolved data, short wavelength is on the opposite side of the film from that shown. Also, the bottom of spark gap appears to the right in these situations, rather than to the left as shown in III.B. This is due to the light being focussed again by the spectrometer and camera, inverting images.

USE OF ROLL FILM BACK

I. Orientation



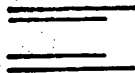
(dark slide on front;
not shown)



Cross-section of inside

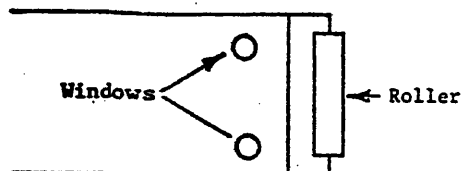
II. To Load

- A. Push "advance release" and turn crank until counter indicates between 20 and S (close to S) and crank can free-wheel.
- B. Insert roll of film in "supply roll" socket. Black side is down, film comes off the top of the roll.
- C. Lift pressure plate and roller. Run tongue of film roll under the pressure plate.
- D. There are four ridges under the area where the pressure plate lies:

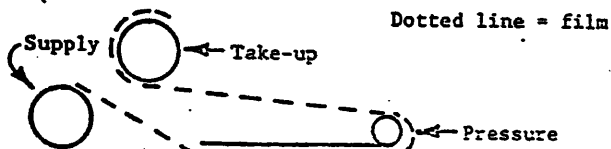


Film must cover the two shorter ridges and lie between the two longer ridges. Otherwise the film may tear later.

- E. Pull film over pressure roller and lower pressure plate. Pull out film until two arrow heads show through the holes in the pressure plate.



- F. Insert tongue of film in take-up reel and mount reel in position. Turn crank until film is just snug. Film path is



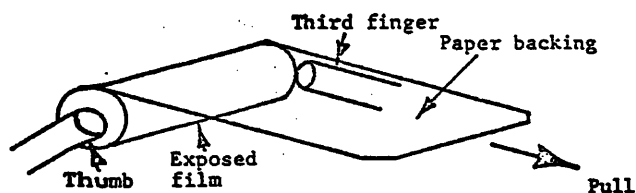
- G. Lower Take-up clips, close rear cover.
- H. Turn counter until a click is heard as "S" catch drops into place.
- I. Insert film holder in spectrograph. Be sure dark slide is down.
- J. Turn crank until cam locks frame 1 in position.
- K. Note that the alignment of the arrows in step E. and the cranking from "S" to "1" in steps H.-J. are engineered to correctly position frame 1.
- H through J should be executed in order.
- III. To advance frames, push the advance release once, then turn the crank until it engages the stop.

IV. Unloading

- A. After shooting frame 10, alternately push the advance release and turn the crank until the film is completely on the take-up spool. This is $\approx 4-5$ frames.
- B. Remove the film back from the spectrograph. Open the back, remove the spool of exposed film, fold under the tongue, and seal the reel closed with the seal provided.

V. Development

- A.** In total darkness, load film onto development reel.
Paper backing must be removed. This can most easily be done as follows:



One end of the film (nearest start of frame 1) is attached to the paper with tape. When this point is reached, discard the paper and the tape and load the film onto the reel.

- B.** For Tri-X, developing conditions which appear to give good contrast in spectra are:

Develop:	10 min	1:1	D-76	18.5°C
Stop:	30 s		SB-5a	
Fix:	10 m		Acid fix	
Wash:	30 m			

FINDING AND INTERPRETING ROLL FILM SPECTRA

I. Roll Identification

A. Each roll is identified by a three-part level. Example:

TX - J - B		
Film type	Spectrometer Identification	A = first roll of this type shot
TX - Tri-X pan	J - Shot on Jarrell-Ash 1 m spectrometer	B = second roll
VP - Verichrome pan	5 - Used 5 m spectrometer	.
Others to be added if used	M - Used McPherson monochromator, etc.	.
	If more than one focal plane is used while running one roll of film, these may be combined. J5 means both JACO and 5M focal planes were used.	Z = 26th roll, etc.

II. Frame Identification

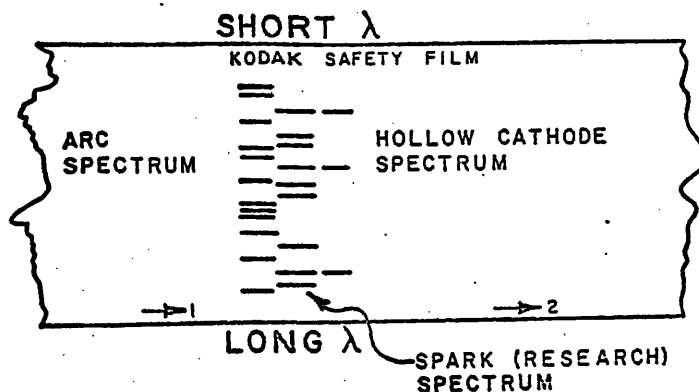
- A. A roll of type 120 film allows 10 frames of $2\frac{1}{4} \times 2\frac{3}{4}$ " to be shot per roll. Commercial film is numbered for 12 frames. Thus commercial film frame numbers should be ignored.
- B. Processed film is stored in plastic notebook film preservers. Each row of the preserver contains two frames, and each preserver can hold eight frames total. Arrangement:

o	1	2	— LABLE BLOCK (EMULSION SIDE DOWN)
	3	4	
	5	6	
	7	8	
o			

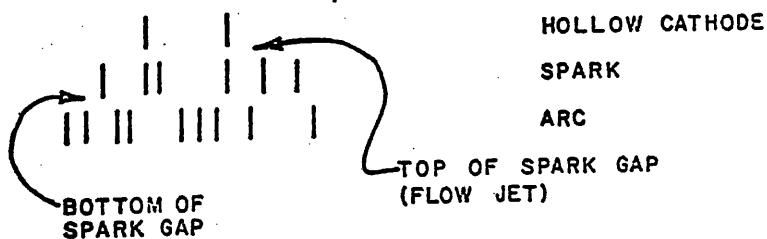
Page 2 similarly would hold frames 9 and 10.

III. Individual Spectra

- A. Five or six spectra appear in each frame.
- B. Shortest λ appears at the left of each spectrum (= toward the top of preserver). A typical spectrum would appear thus on the film (viewed as in the "arrangement" sketch above):



- C. The first spectra shot are those farthest to the left. That is, chronological order of spectra shot and physical order left to right are the same.
- D. Standard configuration:



- E. Correlation of film position and camera back position. When recording data, film position is recorded in terms of physical camera back position in cm. Below is a table relating physical camera position (recorded in lab records) to spectrum number within a frame (spectrum #1 is leftmost in the film preservers).

<u>Spectrum number</u>	<u>JACO camera back position (cm)</u>	<u>5 m camera back position (stop)</u>
1	3.5	4
2	4.5	5
3	5.5	6
4	6.5	7
5	7.5	8
6	8.5	9

IV. Complete Spectrum Identification

In my lab records, discussion concerning a particular spectrum (see for example 3/29/78, p. 1) is given as:

TX - J - A - 10 - 5.5

roll
identification frame Spectrum (third one shot in
this frame)

Appendix G

WAVELENGTH TABLES

Tabulated are observed lines from time integrated spectra of bipolar spark. Cu initial cathode, Al predominant cathode, and Ar spark gas were used at two breaks per half-cycle.

Lines are listed by species and excitation state. Mn, Fe, and Ti lines (impurities in aluminum) were seen but are not listed here. Band systems of N_2 and AlO were observed. Several weak nitrogen and oxygen lines were seen, but are also not listed here.

Wavelengths are those from Striganov's tables or Zaidel's (see explanation in Chapter V).

A question mark after a wavelength indicates either line identification is questionable, or existence of the line above background intensity is dubious.

Wavelengths are in Angstroms.

Al I

2269.1 }	2321.56	2567.98	3050.07	3082.15
2269.2 }	2367.6 multiplet	2575.09	3054.67	3092.8
2312.49	2369.3	2575.4	3057.14	3944.0
2313.53	2370.73	2652.47	3059.03	3961.52
2314.98	2372.07	2660.39	3059.92	
2317.48	2373.3 multiplet	2837.9	3064.29	
2319.06	2374.96	2840.15	3066.15	

Al II

2427.7	2631.55	4159.9
2459.8	2638.5	4663.05
2466.28	2669.17	6226.19
2475.26	2816.18	6231.76
2556.78	3587 multiplet	6243.35
2557.71	3738	
2559.61	3900.68 ?	

Al III

3601.62
3612.35
3702.09
3713.1
4512.535
4529.18
5696.47
5722.65

Ar I

3606.52 ?	4181.88	4333.56
3632.68 ?	4190.7 }	4335.34
3743.765	4191.0 }	4596.1
3770.36	4198.3	4702.31
3781.36	4200.67	4832.4 }
4044.42	4259.36	4832.8 }
4152.54 ?	4266.29	4867.84
4158.59	4272.17	4949.64
	4300.1	5241.1

Ar III

3285.85
3301.88
3311.25
3336.13
3358.49
3480.55
3499.67
3500.58
3514.18
3344.72

Ar II

2437.5	3454.1	3763.50	4076.94	4475.95
2429.45	3464.1 ?	3765.27	4079.58	4481.81
2437.52	3466.3 ?	3770.52	4082.39	4545.045
2444.83	3476.25	3786.38	4103.91	4579.15
2452.74	3491.24 }	3799.38	4112.82 ?	4589.90
2460.64	3491.54 }	3803.17	4128.64	4598.76
2507.33	3509.78	3808.58	4131.73	4609.56
2522.50	3514.39	3809.456	4228.16	4637.23
2525.48	3520.00	3845.41	4237.22	4657.89
2535.25	3521.26	3850.55	4218.67	4682.28
2732.33 }	3535.32	3875.26	4222.64	4726.86
2732.50 }	3545.6	3891.4	4226.6 }	4732.06 ?
2891.6	3545.84	3891.98	4227.0 }	4735.90
2896.56 }	3548.52	3900.62	4277.52	4764.86
2896.75 }	3559.51	3911.57	4282.90	4806.02
2942.89	3561.03	3914.77	4309.1	4847.815
2979.05	3565.03	3925.72 }	4331.2	4879.86
3028.91	3576.61	3926.03 }	4348.06	4889.03
3033.51	3581.61	3928.63	4352.20	4933.2
3161.37	3582.36	3931.235	4362.065	4942.915
3181.04	3588.45	3932.55	4367 ?	4949.4
3212.52	3605.88 ?	3958.36 ?	4370.75	4965.07
3243.69	3620.81	3974.48	4371.33	4972.16
3249.8	3639.83	3979.36	4374.9	5017.16
3293.64 }	3650.89	3988.16	4379.7	5062.04
3293.93 }	3655.3 }	3992.05	4400.1	5065.45
3307.23 }	3656.0 }	3994.29	4401.0	5067.08
3350.93	3628.27	4013.86	4420.91	5090.5 ?
3365.54	3718.21	4035.46	4426.0	5141.8
3376.44	3729.31	4038.81	4430.19	5145.32
3388.53	3737.9	4042.90	4431.00	5165.77
3421.615	3753.52	4072.0	4460.56	5175.43
				5286.89

Cu I

2227.77	3116.35	3319.68	3624.24	4480.35
2230.08	3126.11	3329.64	3627.32	4507.35
2263.08	3128.70	3335.21	3632.56	4509.37
2293.84 ?	3140.31	3337.845	3635.92	4525.11
2303.12	3142.44	3349.29	3641.69	4530.785
2392.63	3146.82	3365.34	3645.23	4539.70
2406.665	3169.68	3381.12}	3648.38	4586.97
2441.64	3175.67	3381.42}	3655.89	4642.58
2458.88	3194.1		3665.73	4651.12
2492.15	3208.23	3402.24	3671.95	4674.72
2593.65	3223.435	3404.66	3676.88	4697.49
2605.26	3224.664	3413.10	3684.67}	4704.59
2618.37	3226.54}	3415.8	3684.93}	4783.4
2734.86 ?	3226.60}	3450.33	3700.54	4794.0
2766.37	3231.18	3454.7	3734.18	5034.36
2824.37	3235.71	3465.4	3741.24	5076.17
2882.93	3243.16	3466.24}	3771.90	5105.54
2961.165	3247.54	3472.14}	3803.49	5111.91
2997.36	3252.22	3476.00	3805.23	5144.12 ?
3010.84	3266.02	3483.76	3860.47	5153.235
3012.00	3268.28	3512.12	4022.63	5200.87
3021.54	3273.96	3520.03	4062.64	5212.78
3022.61	3277.31	3524.23	4073.22	5218.2
3024.99	3279.81	3527.48	4075.57	5220.07
3036.1	3282.72	3530.38	4104.22	5237.65
3063.41	3290.54	3533.75	4123.29	5250.52
3073.80	3292.39}	3599.13	4177.76	5292.52
3088.13	3292.83}	3602.03	4248.96	5360.03
3093.99	3302.79	3610.81	4259.36	5391.6
3099.93	3307.95	3613.76	4275.11	5432.0
3108.5	3317.22	3614.22	4378.20	5700.2
		3621.25	4415.54	5782.13

Cu II

2135.98	2286.64	2443.69	2718.78	4681.99 ?
2148.98	2291.00	2447.43	2721.68	4758.42
2179.40	2292.68	2468.50	2737.34	4812.94
2189.63	2294.37	2473.33	2739.77	4832.24
2192.27	2299.47	2485.79	2745.27	4901.41
2195.67	2309.51	2489.66	2769.67	4909.73
2200.50	2323.01	2506.27	2837.37	4918.37
2210.27	2336.17	2518.95	2857.75	4926.39
2215.10	2348.74	2526.59	2877.70	4931.65
2218.11	2355.01	2529.31	2884.19	4937.2
2226.77	2356.65	2544.80	3158.64	4953.73
2228.87	2369.89	2571.76	3686.55	4980.0 ?
2230.09	2370.75	2590.53	3826.91	4985.5
2230.81	2376.29	2598.81	3842.58	5006.79
2242.62	2384.94	2600.27	4043.5	5009.83
2247.00	2400.11	2620.67	4043.75 }	5012.6 ?
2248.96	2403.34	2666.29	4131.36	5021.3
2254.98	2414.18	2689.30	4179.3	5051.78
2263.78	2424.43	2700.96	4227.94	5093.79
2276.26	2428.92	2703.18	4505.997	5100.1
2278.33	2442.67	2713.51	4555.92	5124.46
				5368.42

Cu III	Ca	C	Mg I	Mg II
2391.73	3933.66	2478.56	2776.69	2790.78
2405.49	3968.47		2778.27	2795.53
2412.32	4226.73		2779.83	2798.00
2482.34			2781.42	2802.70
2609.31			2782.97	2928.63
2641.54			2852.13	2936.51
2643.92			2915.45 ?	
			3829.355	
			3832.3	
			3838.3	
			4165.1	
			4167.27	
			5167.32	
			5172.68	
			5183.6	
B	Be	Na		
2496.78	3130.42	5889.95		
2497.73	3131.07	5895.92		

TITLE OF THESIS Techniques for Observation and Control of
High Voltage Spark Discharge

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Publications Alexander Scheeline and John P. Walters, "Considera-
tions for Implementing Spatially-Resolved Spectrometry Using
the Abel Inversion", Anal. Chem., 48, 1519 (1976).

Alexander Scheeline, D. M. Coleman, R. J. Klueppel, and John P.
Walters, "Computation Procedures for Characterization of High
Voltage Spark Sources", Appl. Spec., 32, 224 (1978).

Alexander Scheeline and John P. Walters, "Experimenta-
lization of Straight Spectrometer Slits"

Date September 21, 1978